Volume 31. No. 1 January, 1956

THE JOURNAL OF HORTICULTURAL SCIENCE

(Formerly The Journal of Pomology and Horticultural Science)

Subscription Rates:
SINGLE NUMBERS 15/- EACH
ONE VOLUME (FOUR NUMBERS) 50/- (RATE FOR CANADA & U.S.A., $7.00) POST FREE

PUBLISHED BY
HEADLEY BROTHERS LTD
109 Kingsway London WC2 England

THE JOURNAL OF HORTICULTURAL SCIENCE

The suggested abbreviation for the title of this publication is *J. hort. Sci.*

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THE NITROGEN CONTENT OF COX'S ORANGE PIPPIN APPLES IN RELATION TO MANURIAL TREATMENTS

By A. C. HULME
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THE work described in the present paper is part of a general study of the relationship between cultural factors and storage behaviour in apples which is being carried out jointly by East Malling Research Station and Ditton Laboratory.

It has been suggested that keeping quality of apples is related to their nitrogen content. This suggestion has never been conclusively proved, but there is some experimental evidence in its support and it is a belief widely held among fruit growers that the application of excessive amounts of nitrogen to the soil results in apples which do not keep well. However, it has not yet been shown to what extent the application of nitrogen to the soil affects the nitrogen content of the fruit, and further it is clear that level of nitrogen is not the only factor involved in keeping quality, whether it be a question of resistance to fungal attack, susceptibility to low temperature breakdown, carbon dioxide injury in gas storage or other storage disorders.

This paper gives the results of the determination of total protein and non-protein nitrogen, obtained in 1953, from two series of Cox's Orange Pippin apples. The first series consisted of fruit from trees included in a long term manurial trial at East Malling Research Station ; the second comprised a range of samples from commercial orchards in Kent, Sussex and Essex, selected to cover a range of reputedly good and bad keeping fruit. These results, though limited, clearly indicate the relation between protein and soluble nitrogen and the extent of variation in nitrogen content of apples from commercial orchards. The results obtained with the fruit from the trial plots show the effects of manurial and other soil treatments on the nitrogen content of the fruit. These findings need to be checked and extended by further observations and it is planned to collect data on nitrogen content and keeping quality over as wide a range of varietal types as possible.

MATERIAL AND METHODS.

(*a*) *Fruit from East Malling Research Station.* This was obtained from Cox's Orange Pippin trees on rootstock M.XII which were 24 years old in 1953, and which had been used in a long term manurial experiment. The eight basic treatments, replicated eight times, consisted of N, P, K in various combinations but from 1937 to 1953 all plots had received, in addition to the original treatments, a dressing of sulphate of potash. Samples of fruit were taken only from plots which had the following treatments, the figures giving annual fertilizer rates in cwt. per acre :

		Sulphate of ammonia	Sulphate of potash
"N"	1931-36	1½	0
	1937-40	1½	2
	1941-52	3	2
	1953	6	2

		Sulphate of ammonia	Sulphate of potash
"K"	1931-36	0	2
	1937-53	0	4
"NK"	1931-36	1½	2
	1937-40	1½	4
	1941-52	3	4
	1953	6	4

The plots denoted "N", though they received some potash fertilization, had a N/K ratio more than double that of the "NK" plots, viz. a ratio of 57 to 34 as against 57 to 78.

In April, 1953, half the replicates were grassed down and the supplementary dressing of potash was omitted. Samples of fruit were taken from the treatments "N", "K" and "NK", both under grass and under clean cultivation, of which there were now four replicates each containing a single tree of Cox on M.XII.

TABLE I.

Manurial Trials. E.M.R.S., 1953. Cox's Orange Pippin apples.

Treatment	Plot number	Total nitrogen		Protein nitrogen			Soluble nitrogen	
		mg./apple	mg./100 g. fresh wt.	mg./apple	mg./100 g. fresh wt.	% T.N.	mg./apple	mg./100 g. fresh wt.
"N" grass	F10	74·6	69·4	43·6	40·6	58·5	31·0	28·8
	F1	57·6	59·4	37·9	39·1	65·8	19·7	20·3
	E7	61·4	61·4	40·4	40·4	65·8	21·0	21·0
	D2	61·9	66·2	37·9	40·5	61·2	24·0	25·7
	Means	—	*64·1*	—	*40·1*	*62·8*	—	*24·0*
"N" cult.	D11	83·5	72·8	45·9	40·0	54·9	37·6	32·8
	C7	83·0	77·2	47·8	44·4	57·5	35·2	32·8
	A2	76·3	78·6	42·2	43·4	55·2	34·1	35·2
	B7	74·7	76·4	42·7	43·7	57·2	32·0	32·7
	Means	—	*76·2*	—	*42·9*	*56·2*	—	*33·4*
"K" grass	B1	49·8	49·8	35·6	35·6	71·4	14·2	14·2
	A6	45·8	56·0	32·6	39·8	71·1	13·2	16·2
	C5	48·2	47·8	36·2	35·9	75·0	12·0	11·9
	G12	45·3	47·9	32·4	34·2	71·4	12·9	13·7
	Means	—	*50·4*	—	*36·4*	*72·2*	—	*14·0*
"K" cult.	C9	73·5	62·6	45·5	38·8	62·0	28·0	23·8
	E4	48·2	61·2	31·4	39·9	65·2	16·8	21·3
	C2	54·0	58·2	36·2	38·9	66·8	17·8	19·3
	Means	—	*60·7*	—	*39·2*	*64·7*	—	*21·5*
"NK" grass	D12	73·1	66·6	42·9	39·1	58·7	30·2	27·5
	D8	74·8	72·6	44·2	42·9	59·0	30·6	29·7
	B3	66·5	80·4	38·0	45·9	57·2	28·5	34·5
	A7	70·0	72·2	41·9	43·2	59·8	28·1	29·0
	Means	—	*73·0*	—	*42·8*	*58·7*	—	*30·2*
"NK" cult.	F9	95·1	80·0	52·0	43·8	54·8	43·1	36·2
	C3	75·4	79·2	43·4	45·6	57·6	32·0	33·6
	F8	84·4	76·8	49·1	44·7	58·2	35·3	32·1
	Means	—	*78·7*	—	*44·7*	*56·9*	—	*34·0*

Each sample of apples consisted of 25 fruits selected at random from the crop from each of the four trees—except that fruit was available from only three trees of treatments " K " cult. and " NK " cult. Since the fruit could not be frozen immediately after harvesting to await analysis (Hulme, 1936), it was placed at 10° C. for about a week followed by two to three days at 0° C. The apples were then halved, the seeds removed and the remaining tissue frozen at —20° C. to await analysis.

(*b*) *Fruit from various commercial orchards.* Samples were obtained from Sussex (K2 and K3) ; from irrigated and similar non-irrigated trees (CB1 and CBN1) and other sources in Essex (FPU and FPN) ; from Kent (5A, 5B and West Peckham 5) and from Suffolk (RCF, RG and RP).

In the present work sub-samples of 25 fruits were selected from larger samples of 100 fruits stored at 0° C. from September, 1953, to 10th February, 1954. In making up these sub-samples the proportion of large, medium and small fruits was kept the same as in the original larger sample of 100 fruits.

Details of the sources of this fruit and storage results will be published elsewhere.

Method of analysis.

Whole fruits (minus the seeds) were used for this purpose. Determinations of total, non-protein (80 per cent. ethanol-soluble) and protein nitrogen (by difference) were carried out exactly as already described (Hulme, 1950). These methods, with minor modifications, have been in continuous use at Ditton over the past 20 years.

RESULTS.

The results obtained with the series of samples from East Malling Research Station are shown in Table I ; those for the series of commercial samples appear in Table II. Mean values for the three manurial treatments, and for grass *v.*

TABLE II.

Commercial samples of Cox's Orange Pippin apples, 1953 (ex store at Ditton Lab., 10th February, 1954).

Code No.	Total nitrogen		Protein nitrogen			Soluble nitrogen	
	mg./apple	mg./100 g. fresh wt.	mg./apple	mg./100 g. fresh wt.	% T.N.	mg./apple	mg./100 g. fresh wt.
K2	64·8	65·4	43·2	43·8	66·7	21·3	21·6
K3	56·0	61·0	40·4	44·0	72·2	15·6	17·0
CB1	70·3	67·4	48·9	47·2	69·5	21·4	20·0
CBN1	68·0	78·2	38·7	44·5	56·9	29·3	33·7
FPU	79·1	87·0	49·2	54·1	62·2	29·9	32·9
FPN	61·0	74·4	37·8	46·1	62·0	23·2	28·3
5A	59·9	70·6	38·2	45·0	63·7	21·7	25·6
5B	58·3	70·0	33·9	40·6	58·2	24·4	29·4
RCF	72·7	77·8	42·9	45·9	59·1	29·8	31·9
RG	63·5	69·9	37·2	41·0	58·6	26·3	28·9
RP	55·5	83·2	31·5	47·2	56·7	24·0	36·0
West Peckham 5*	90·5	92·3	49·5	50·5	54·6	41·0	41·8

* This sample contained many apples with slight rots. The rotted tissue was removed before analysis and the weight of the discarded tissue is allowed for in the results.

cultivation, in the East Malling results are shown in Table III; significant differences between means at the 5 per cent. level are shown for each set of means in the Table.

TABLE III.

Mean values and significant differences (mg./100 g. fresh weight). East Malling data.

	Total nitrogen			Protein nitrogen		
Fertilizer treatment ..	"NK"	"N"	"K"	"NK"	"N"	"K"
Means	75·8	70·2	55·5	43·7	41·5	37·8
Significant difference, P=0·05	4·08			1·99		
Cultural treatment ..	Cult.		Grass	Cult.		Grass
Means	71·9		62·5	42·3		39·8
Significant difference, P=0·05	3·33			1·62		

DISCUSSION.

It will be seen from Table III that there is a significant response at the 5 per cent. level, both in total and in protein nitrogen, to manurial treatment. Treatments "N" and "NK" increased both total and protein nitrogen, treatment "NK" having had a significantly greater effect than treatment "N".

Cultivation as opposed to grassing-down significantly increased both total and protein nitrogen. The total nitrogen response is significant down to the 0·1 per cent. level, that of protein nitrogen only down to the 1 per cent. level. It will be noted also that, as in the manurial treatments, the total nitrogen response greatly exceeded the protein nitrogen response, an indication that, even at moderate contents of total nitrogen, net conversion to protein of soluble nitrogen entering the apple fruit tends to be limited.

The conclusion last mentioned also emerges from a survey of the data in Table II. In contrast to the very considerable range in total nitrogen concentration (from 61·0-92·3 mg./100 g. fresh weight in fruit from different sources) protein nitrogen varies very little, ranging only from 41·0-54·1 mg./100 g. Tomkins (1954) has suggested, as a result of an examination of the available data, that the protein content of the commoner English varieties of apple may vary, at least within a variety, only between fairly narrow limits and that the soluble nitrogen is increased more readily than protein nitrogen by the application of nitrogenous fertilizers. Certainly, experiments carried out at Ditton in 1935 and 1936, in which nitrate, urea and asparagine were injected into Bramley's Seedling trees, showed that while nitrogen could be greatly increased in the fruits, especially when urea was used, only a small proportion of this nitrogen appeared as extra protein (Hulme, 1951).

The data in Tables I and II have been used to construct the graphs shown in Figs. 1 and 2. It will be seen that the values of soluble nitrogen in relation to

protein nitrogen fall close to a straight line and that fruits containing low concentrations of protein nitrogen contain very little soluble nitrogen. As the concentration

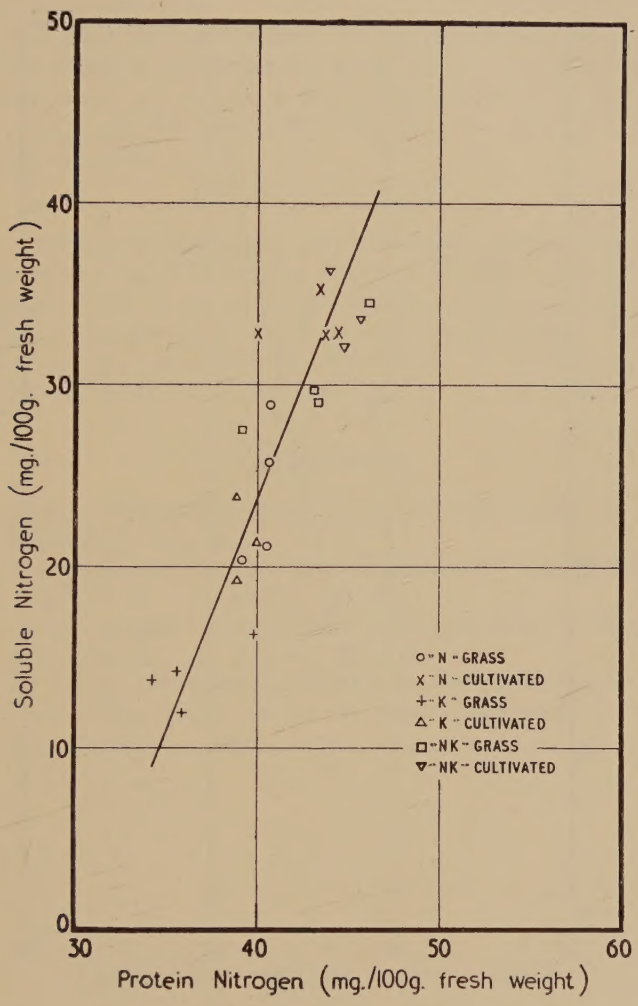

FIG. 1.

Relation between protein and soluble nitrogen in Cox's Orange Pippin apples from trees included in a long term manurial trial at East Malling.

of protein nitrogen increases above 30-40 mg. per 100 g. fresh weight the concentration of soluble nitrogen increases at about twice the rate of that of the protein nitrogen.

Values for total nitrogen lower than about 40 mg. per 100 g. fresh weight are, in the experience of the Ditton Laboratory, seldom met with in Cox's Orange Pippin apples grown under normal conditions.

For Bramley's Seedling apples—a culinary variety—present indications are that the range of protein nitrogen contents is somewhat lower than for Cox's Orange Pippin (Hulme, 1951).

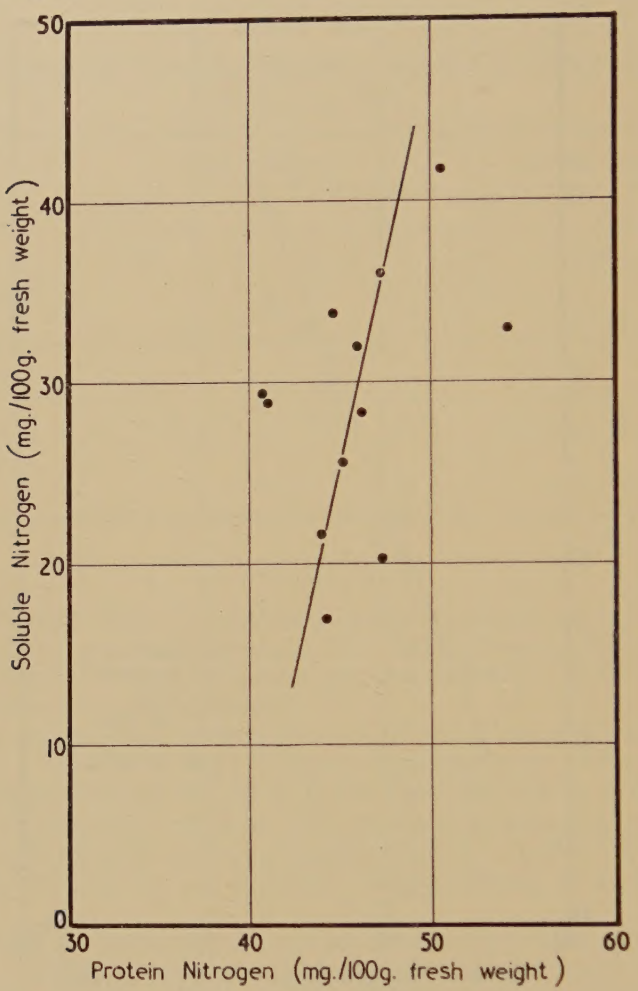

FIG. 2.

Relation between protein and soluble nitrogen in Cox's Orange Pippin apples obtained from a number of commercial orchards in 1953.

SUMMARY.

(1) Data are presented for the total, soluble and protein nitrogen content of two series of samples of Cox's Orange Pippin apples, one series consisting of fruit from comparable trees receiving nitrogen and potash fertilizers on both grassed-down and cultivated plots, and the other consisting of fruit from commercial orchards in different parts of the country.

(2) It is shown that both total and protein nitrogen are increased in the fruit when the trees are given ammonium sulphate ; if potash is also given, the nitrogen content is further increased. The nitrogen content of the fruit is lower from grassed-down than from cultivated plots.

(3) While the total nitrogen content of the fruit varies widely over the two series, the protein nitrogen differences are more limited. It is suggested that, with a nitrogen content of 30 mg. per 100 g. fresh weight, most of the nitrogen would be in the form of protein and that, above this value, soluble nitrogen increases twice as rapidly as protein nitrogen.

ACKNOWLEDGMENTS.

The work described in this paper, part of a joint investigation undertaken by the Ditton Laboratory and East Malling Research Station, was carried out as part of the programme of the Food Investigation Organization of the Department of Scientific and Industrial Research, and is published by permission of the Director.

The chemical analyses described were done by Mr. E. F. King and the data were analysed statistically by Mr. G. H. Freeman.

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(*Received* 21/7/54.)

STUDIES ON THE EFFECTS OF LIGHT QUALITY ON THE GROWTH AND DEVELOPMENT OF PLANTS

I. APPARATUS FOR THE GROWING OF PLANTS UNDER CONTROLLED LIGHT AND TEMPERATURE CONDITIONS

By DAPHNE VINCE*, M. G. CLARKE†, H. R. RUFF† and R. H. STOUGHTON*
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THE responses of plants to light of different wave-lengths, although the subject of many experiments, still present no clear picture. In part, this is due to the complexity of the physiological systems concerned; different species, even varieties of the same species, may respond differently, while other factors such as light intensity and temperature may modify the response. A further difficulty is that of providing adequately controlled environmental conditions.

In early experiments a wide range of plant species was grown in various wave-lengths in light of sufficient intensity for photosynthesis, obtained by filtering sunlight through coloured glasses (Schanz, 1918, 1919 ; Popp, 1926 ; Shirley, 1929). The cut-off of the filters, particularly at the blue end of the spectrum, was not sharp so that wave-band limits were ill-defined and, because of differences in the percentage transmission of the filters, energy levels in the different wave-length regions were unequal. Control of light intensity and quality was later achieved by the use of artificial light sources combined with glass or gelatin filters (Hibben, 1924 ; Withrow, 1941 ; Went, 1941 ; Rohrbaugh, 1942 ; Withrow and Price, 1953) and narrow wave-bands of high spectral purity have been obtained by means of a spectrograph (Weintraub and McAlister, 1942 ; Parker, Hendricks, Borthwick and Sculley, 1946). Experimentation has been limited in most cases either by low light energy level or by the smallness of the area illuminated. Consequently, while the morphogenic effects of light of different wave-lengths have been critically studied in a few selected species (leaf expansion and internode elongation in *Pisum*, by Went, 1941, and Parker *et al.*, 1949 ; elongation of the mesocotyl of *Avena*, by Weintraub and McAlister, 1942, and Weintraub and Price, 1947 ; leaf expansion in *Phaseolus* and *Zea*, by Withrow, Klein, Price and Elstad, 1953), little attention has been paid in recent years to the effects of the wave-length of light on the growth and development of other plants.

The apparatus described in this paper was designed to provide light at wave-lengths within one of three broad divisions of the visible spectrum, namely 400-500, 500-600, and 600-700 mμ, and at an energy level above the compensation point at favourable growing temperatures. It allows of the illumination of a relatively large area (6×4 ft.) so that adequate numbers of plants could be grown for growth analysis studies.

Since the start of the investigations described in the present series of papers, a number of similar, but smaller, wave-length compartments at Wageningen have been described by Wassink and Stolwijk (1952).

DESCRIPTION OF THE EQUIPMENT.

GENERAL.

The illuminating units are contained in four of nine compartments into which the " illumination building " is divided. This brick building is connected through a swing door to the central corridor of an experimental glasshouse block. The compartments are separated by heavy, black gaberdine curtains, facilitating heat exchanges between compartments, while preventing leakage of light from one compartment to another. All internal surfaces, other than the dividing curtains, are painted white.

All experimental plants are grown on wheeled trolleys constructed of " Dexion " aluminium angle strip, with tops of expanded aluminium mesh of $\frac{1}{8} \times \frac{1}{8}$ in. strands. The trolleys are 3×2 ft. and are of two heights, namely $2\frac{1}{2}$ and $1\frac{1}{2}$ ft. Plants receiving light of restricted wave-lengths as a supplement to daylight remain in the glasshouse from 8 a.m. to 4 p.m. and in the illumination compartments from 4 p.m. to 8 a.m., during which period they receive the required duration of supplementary light. Other plants are grown entirely under the artificial light sources.

CONTROL OF TEMPERATURE.

The walls of the building provide good insulation against heat losses and gains, and the temperature remains reasonably constant within the building, even without regulation by artificial means.

The building is heated by two low-pressure steam pipes, passing along one wall of each compartment. The pipes are controlled by an electro-magnetic valve, operating at the point of entry into the building, which is so wired that the thermostat regulating the valve can be placed in any compartment.

Rises in temperature are prevented by a refrigerated air conditioning plant powered by two $3\frac{1}{2}$ h.p. compressors. The cooled air is circulated by means of an electric fan and enters each chamber through two ducts at the back corners of each compartment. The air inlets are near the ground and consist of laterally flattened fins, 8 in. long, which are movable through an arc of some 60 degrees so that the air flow may be directed towards, or away from, the plants. The flow of air through each duct can be regulated independently by means of a sliding damper above the outlet. The cooling plant is also controlled by a thermostat, which is normally placed in the compartment with the greatest lamp loading, the dampers in the remaining chambers being manually adjusted to give the required temperature.

By means of a system of dampers it is possible to regulate the amount of air taken from the external atmosphere and the amount of recirculation of air within the building. In hot weather the cooled air is largely recirculated within the system by the extraction of air from the compartments through roof vents into a duct, through which the air is returned to the cooling chamber. This system avoids the necessity of cooling large volumes of warm air from the external atmosphere to the temperature maintained within the building. In winter, air from outside is cooled, if necessary, passes into the chambers and is extracted to the outside by means of a further fan placed at the end of the ducting system.

PLANT ILLUMINATOR UNITS.

The light sources used are 5 ft. 80-watt fluorescent lamps of various colours, some of which are used with filters. The illuminators are made of an aluminium strip framework, which holds a number of backbone-type fluorescent lamp fittings,

each containing the necessary choke, capacitor and starter for the associated lamp. The number of lamp fittings in each illuminator is based on laboratory measurements of the total radiation output of the lamps ; the blue and red units contain 21 fittings, the green and white ones 11 and 7 respectively.

The illuminators are made in the shape of an inverted trough as shown in Plate I, Fig. 1, and they are suspended by chains from the ceiling of each compartment at such a height that the base of the framework is a little above the level of the top of the trolley carrying the plants. The angle which the two side pieces make with the top of the frame can be varied to improve the distribution of light over the area containing the plants.

The vertical distribution of light is fairly uniform from the trolley surface to a height of about 1½ ft. above it. The light intensity is, therefore, maintained at approximately the same level, even though differences in growth rate occur. The height of the fittings is not varied ; the energy levels are equalized by varying the numbers of tubes, and the experiments are terminated before the plants reach a height of 1½ ft.

The area of illumination is 4 × 6 ft., so that four trolleys can be placed under each illuminator.

Radiation characteristics of the light sources.

The three coloured light sources have been designed to divide the visible spectrum into three bands, each approximately 100 mμ wave-length wide.

For the blue band, fluorescent lamps coated with calcium tungstate phosphor are used and, to limit the radiation as closely as possible to the 100 mμ width, each of the lamps is enclosed in a cylindrical colour filter of Strand " Cinemoid " No. 32 (Medium Blue) cellulose acetate sheet. This reduces considerably the energy radiated from the phosphor at wave-lengths longer than about 520 mμ and completely absorbs the unwanted spectral line radiation from the mercury vapour itself at 546 mμ and 578 mμ. It had previously been checked that the colour of this filter material was stable when wrapped around a fluorescent lamp for a period of 1,000 hours' burning. The spectral character of the lamp and the effect of the filter on this are shown in Fig. 2.

For the green band, fluorescent lamps coated with zinc silicate phosphor are used. This phosphor has a comparatively narrow radiation band, so that a colour filter is necessary only to absorb the spectral line radiation from the mercury vapour at 405 mμ and 436 mμ. Fig. 3 shows that the colour filter, Strand " Cinemoid " No. 1 (Yellow), does this effectively without seriously reducing the phosphor radiation between 500 and 600 mμ wave-length.

For the red band, lamps employing cadmium borate phosphor with an internal red pigment coating are used. Similar characteristic curves are given for this lamp in Fig. 4, which shows that the pigment layer effectively absorbs all violet and green mercury vapour spectral lines and transmits only a small proportion of the yellow line.

The spectral radiation characteristic of the white (" Daylight ") fluorescent lamps is shown in Fig. 5.

The number of lamps used for each illuminator varies inversely with the overall radiation efficiency of the sources, since the efficiency of generation of radiation is not the same for all phosphors used and the transmissions of the filters differ.

PLATE I

Fig. 1.
General view of illumination outfit.

[face p. 10

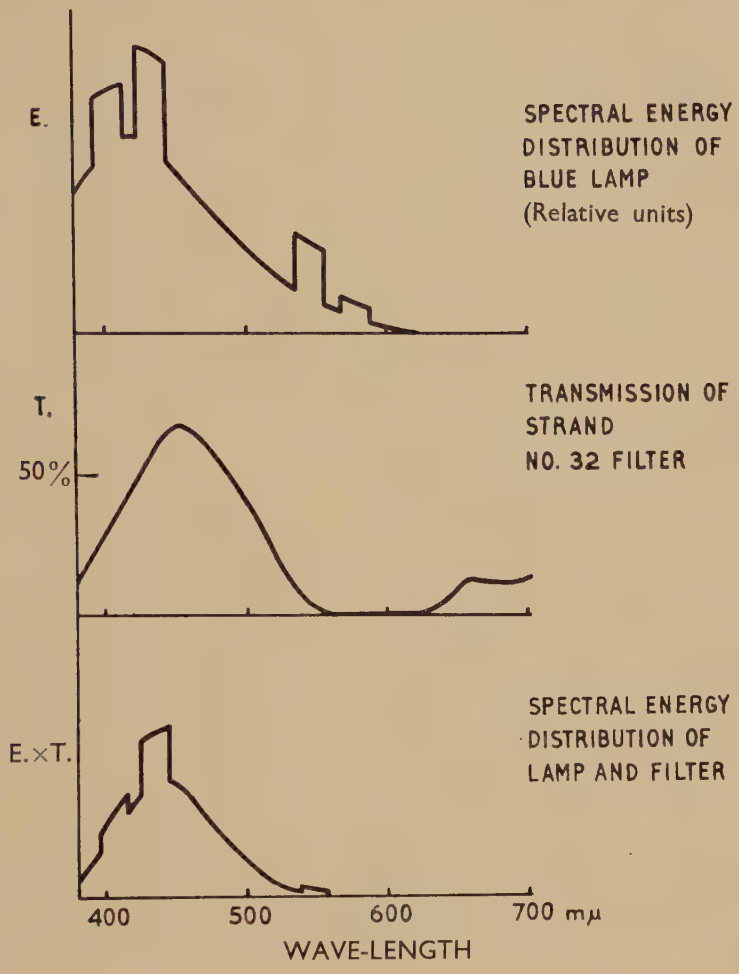

FIG. 2.
Radiation characteristics of blue source.

MEASUREMENT OF RADIATION.

While the numbers of fittings in each illuminator were chosen originally on the basis of laboratory measurements of radiation output of the lamps with their respective filters, actual radiant energy intensities are periodically measured under working conditions in the illumination compartments and the numbers of lamps used in each experiment are based on these measurements.

A Hilger-Schwarz compensated vacuum thermopile, calibrated at intervals against a standard tungsten-filament lamp, is used for all direct measurements of energy. It is housed in a metal container packed with cotton wool to insulate it from fluctuations of the ambient temperature. The values for total visible radiation are obtained by using a combination of two filters with the thermopile, a water filter

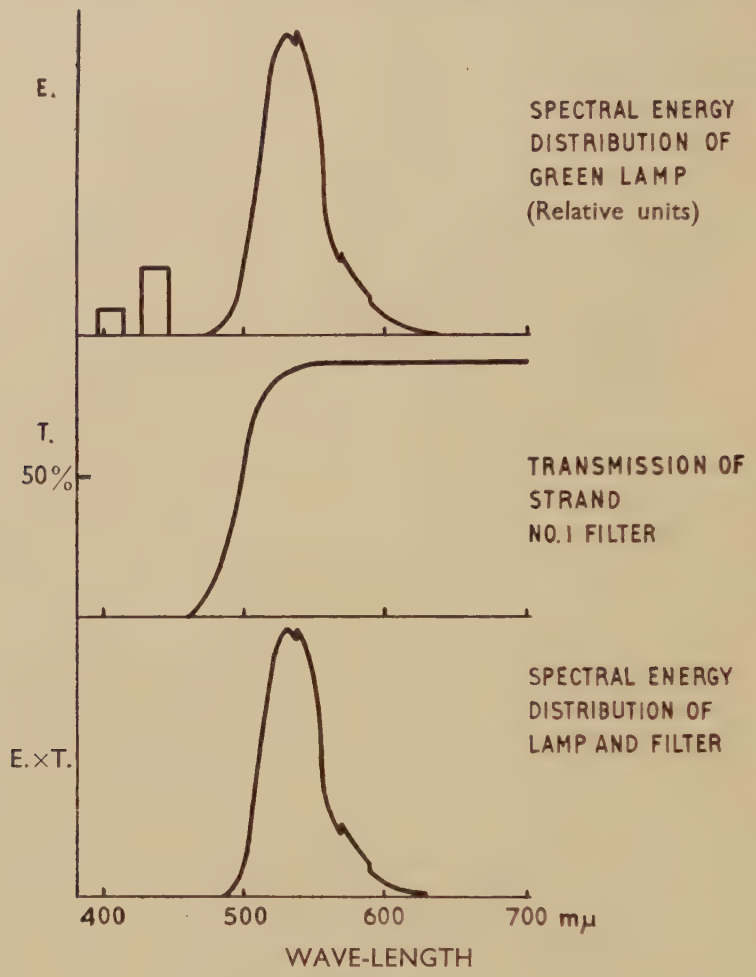

Fig. 3.
Radiation characteristics of green source.

1 cm. thick and a Chance glass filter OX5, 2 mm. thick (Cooper and Hawkins, 1940). Two readings are taken with each source :

(1) W (Water filter).
(2) W + X (Water filter and OX5).

The approximate energy below 750 mμ is given by W — (W + X), and that between 750 and 1,400 mμ by W + X. The factor for loss by reflection from the water cell is approximately 10 per cent.

Check radiation measurements are also made indirectly with a barrier-layer photo-cell. The spectral sensitivity of this cell for an output current of 1 micro-amp. was previously determined over the wave-length range 400 to 700 mμ at wave-length

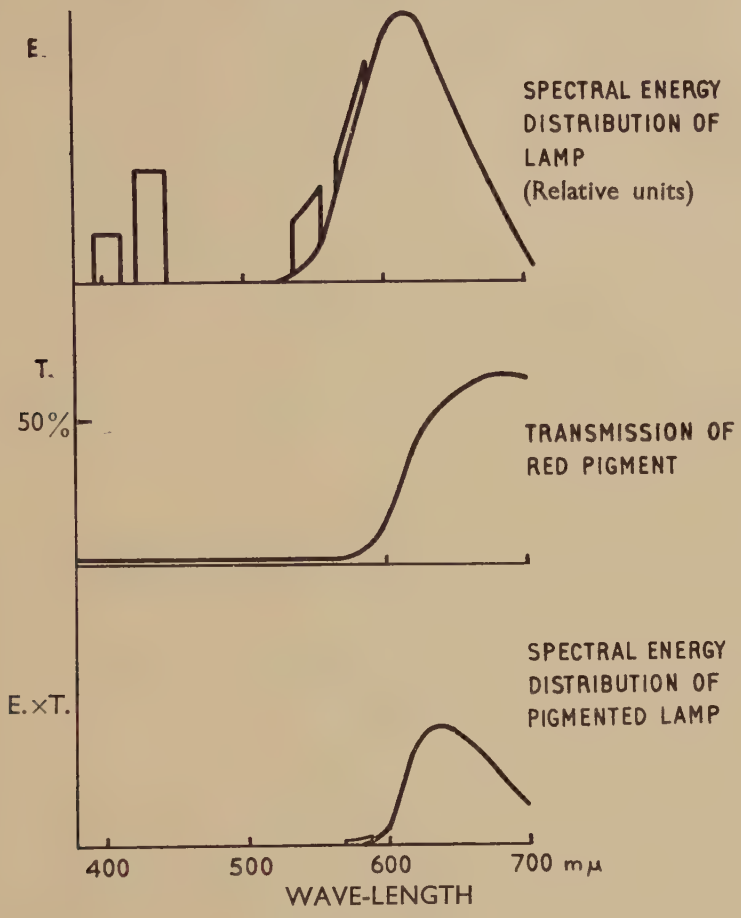

FIG. 4.
Radiation characteristics of red source.

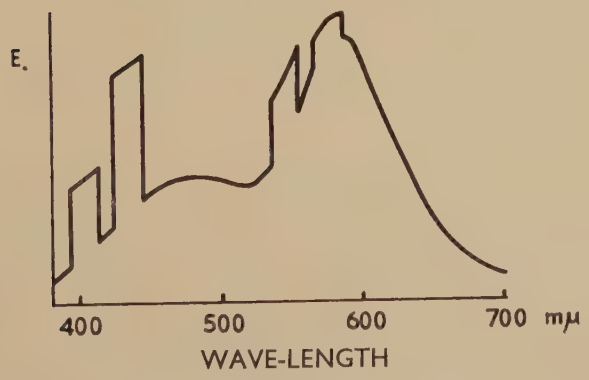

FIG. 5.
Radiation characteristics of white source.

intervals of 20 mμ, with the calibrating beam incident normally and of uniform intensity over the cell area. Calculation of the factor required to correct the meter readings for the spectral sensitivity of the cell was made for each source by arithmetical integration of the combined cell sensitivity and source spectral radiation curves.

The variation in light flux across the irradiated area is estimated with a barrier-layer photo-cell inside an opal glass integrating sphere, 15 cm. in diameter. The cell, of diameter 2·9 cm., is mounted on a support at a position one-third of the radius from the centre ; the support is painted white to increase the internal reflection. This instrument is not used for absolute measurements, but only for estimates of variation in light intensity under any one source. The total variation in intensity across the utilized surface is approximately 18 to 20 per cent. and the distribution of light is similar in each compartment. The effect of variation in light energy across the irradiated area is eliminated as far as possible by sampling technique.

The maximum total available energy is limited by the blue lamps and is approximately 8,000 ergs/cm.^{2}/sec.

SUMMARY.

Controlled environment rooms are described in which large numbers of young plants may be grown for growth analysis and general growth studies. The air temperature is regulated by a refrigerated air-conditioning plant and/or low pressure steam-heating pipes, each controlled thermostatically. The light sources are coloured fluorescent lamps, some of which are used with filters, and the visible spectrum is divided into three bands each approximately 100 mμ wide. " Daylight " fluorescent lamps are used for the control series in white light.

The lamps are arranged in the form of an inverted trough in order to obtain a reasonably uniform vertical and horizontal distribution of light energy. This reduces differences in light intensity at the leaf surfaces of plants in the different compartments, which would arise as a result of varying rates of growth. Equal energies incident on the plants are obtained by varying the number of fluorescent lamps in each illuminator unit in inverse ratio to their efficiency as determined with a vacuum thermopile.

ACKNOWLEDGMENTS.

The gift of the illuminator units by the British Thomson-Houston Company and the advice and guidance of Mr. L. J. Davies, Director of Research of the Company, are gratefully acknowledged.

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STUDIES ON THE EFFECTS OF LIGHT QUALITY ON THE GROWTH AND DEVELOPMENT OF PLANTS

II. FORMATIVE EFFECTS IN *LYCOPERSICON ESCULENTUM* AND *PISUM SATIVUM*

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NUMEROUS studies have been made of the formative effects on plants of light of different wave-lengths, but some of the results have been conflicting. Reports of a decrease in internode length and total stem length with increase in wave-length include those of Withrow (1941) for *Phaseolus vulgaris* and *Pisum sativum* seedlings ; Rohrbaugh (1942) for *Phaseolus vulgaris* ; Went (1941) and Parker, Hendricks, Borthwick and Went (1949) for *Pisum sativum* Little Marvel ; Weintraub and McAlister (1942) and Weintraub and Price (1947) for mesocotyls of some grasses ; and Johnston (1937) and Goodwin and Owens (1948) for first internode in *Avena*. These experiments were carried out at low energy levels (1 to 2,500 ergs./cm.^{2}/sec.) and with narrow band radiation. In other experiments, where wider wave-bands, often associated with higher energy levels, have been employed, increases in internode length and total stem length with increase in wave-length have been reported. These reports include those of Shirley (1929) for *Geum canadense*, *Helianthus cucumerifolius* and *Galinsoga parviflora* ; Teodoresco (1929) for *Sempervivum tectorum*, *Sedum Telephium*, *Sophora japonica* and *Helianthus tuberosus* ; McIlvaine and Popp (1940) for *Brassica rapa* seedlings ; van Schoor (1950) for *Elodea canadensis* ; Wassink and Stolwijk (1952) for *Lycopersicon esculentum*, *Cosmos bipinnatus* and *Iberis coronaria*. Total stem length and internode length have also been reported to increase when the blue end of the spectrum only is removed, in *Cucumis*, *Fuchsia*, *Chrysanthemum*, *Lobelia*, *Begonia* and *Oxalis* (Schanz, 1918, 1919) and in *Nicotiana tabacum*, *Petunia hybrida*, *Helianthus cucumerifolius*, *Soja max*, *Mirabilis jalapa*, *Lycopersicon esculentum* and *Coleus blumei* (Popp, 1926). Some of this work has been criticized on the grounds that unknown amounts of infra-red and ultra-violet radiation were present when incandescent and mercury vapour lamps were used as light sources (Rohrbaugh, 1942), while van Schoor (1950) has drawn attention to the fact that results may differ at different energy levels.

In the present experiments a study was made of the morphogenic development of one plant reported to show increased internode length, and of one plant reported to show decreased internode length with increase in wave-length, to compare their behaviour when grown under the same light sources. The species selected were the pea, *Pisum sativum* and the tomato, *Lycopersicon esculentum*. A further reason for choosing these two species was that *Pisum* has abundant food reserve in the seed whereas *Lycopersicon* has relatively little.

EXPERIMENTAL.

Details of the apparatus have been given in a previous paper (Vince, Clarke, Ruff and Stoughton, 1956).

For each species the response has been determined at two energy levels ; for *Pisum* at approximately 1,500 and 7,500 ergs/cm.²/sec. and for *Lycopersicon* at approximately 3,000 and 7,500 ergs/cm.²/sec. Seeds of the pea varieties were sown in the pots directly in the illumination chamber ; tomato seedlings were raised in a glasshouse and transferred to the light chambers two to three weeks after sowing. All plants were grown in John Innes potting compost (JIP_1) in $3\frac{1}{2}$ in. plastic pots.

RESULTS WITH *Pisum sativum*.

A. Mean energy level 1,458 ergs/cm.²/sec. ± 22·7. Range 1,408-1,505.

Seeds of the varieties Meteor and Alaska were sown on 13.2.53, and the plants were grown in the red, green, blue and white compartments in a 10-hour photoperiod at 60° F., and in darkness at the same temperature. Ten representative plants from each treatment were measured on 2.3.53 and 9.3.53, and dissected to determine the stage of flowering. The results are given in Table I.

TABLE I.

Effect of wave-length of light on growth of Pisum sativum, *12 and 19 days from germination. Mean energy level—1,458 ergs/cm.²/sec.*

	Variety	Date	Light Treatment					L.S.D. at P=0·05
			Blue	Green	Red	White	Dark	
Total stem length (cm.)	Meteor	Mar. 2	11·1	8·8	6·4	6·8	23·4	1·48
		Mar. 9	14·0	12·3	8·9	8·8	30·0	2·06
	Alaska	Mar. 2	26·7	28·6	25·7	22·6	33·4	1·96
		Mar. 9	27·0	32·7	27·8	27·2	34·6	4·00
Mean internode length (cm.)	Meteor	Mar. 2	2·9	2·3	1·6	1·6	6·4	0·47
		Mar. 9	3·1	2·7	1·9	1·7	7·1	0·31
	Alaska	Mar. 2	7·8	7·9	7·0	6·1	10·8	0·50
		Mar. 9	7·4	8·0	6·8	6·4	10·6	0·78
Mean leaflet length (cm.)	Meteor	Mar. 2	1·5	1·6	1·7	1·7	1·0	0·11
		Mar. 9	1·6	1·6	1·8	1·8	1·0	0·12
	Alaska	Mar. 2	1·3	1·2	1·3	1·3	0·8	0·09
		Mar. 9	1·3	1·2	1·3	1·5	0·7	0·13

The two varieties, though grown under identical conditions, did not respond in the same way to the different wave-length bands.

Total stem length. In Meteor, length decreased with progressive increases in wave-length ; in white light the length was the same as in red. Alaska showed smaller and less consistent differences with changes in wave-length, the stem length in green being significantly greater than in red, blue or white light. In both varieties length was significantly greater in darkness than in any light treatment.

Mean internode length. In Meteor, internode length also increased with progressive increases in wave-length ; in white light the length was the same as in red. In Alaska, the mean internode lengths in green and blue light were the same, and significantly greater than in red or white. Maximum internode length in both varieties occurred in darkness.

Mean leaflet length. The length of the leaflets showed trends opposite to those for stems and internodes. In Meteor, length increased with increase in wavelength, white producing the same response as red. In Alaska, the leaflet length was slightly less in green than in blue, red or white light, but the difference was significant only on 2nd March. In both varieties the shortest leaflets occurred in darkness.

Flower initiation occurred in all treatments but the rate of development of the primordia was delayed in darkness as compared with the 10-hour light treatments. These results do not confirm those of Stolwijk (1952) who found that, although flower primordia in Alaska were initiated in darkness, initiation was completely suppressed when the plants were grown in several wave-bands at 1,000 ergs cm.^{2}/sec. in an 8-hour photoperiod. In both varieties the rate of development of the primordia was more rapid at longer wave-lengths but the number of nodes to the first flower did not differ in the different treatments.

B. Mean energy level 7,597 ergs/cm.^{2}/sec. ± 235·9. Range 6,895-7,896. (The green was lower, 6,895, in this experiment owing to lamp failure.)

Seeds of the variety Meteor were sown on 21.10.53, and the plants grown in the compartments in a 17-hour day at a mean temperature range of 58-66° F. Ten representative plants from each light treatment were measured on 26th November, 26 days after germination ; the results are given Table II. The energy level was sufficiently high for the plants to gain appreciably in dry weight, and the rate of growth was faster in the red and white compartments. The total stem length and internode lengths were greatest in plants grown in blue light ; the internode lengths in red and white were very slightly shorter than in green, but not significantly so except for the first internode. The leaflet length was least in blue, but there was no difference between the other light treatments.

TABLE II.

Effect of wave-length of light on growth of Pisum sativum *26 days from germination. Mean energy level—7,597 ergs/cm.^{2}/sec.*

Light treatment	No. of leaves	Total stem length (cm.)	Internode length (cm.)				Leaflet length (cm.)			Total dry weight (mg.)
			1	2	3	4	1	2	3	
Blue ..	4·3	14·9	1·3	2·1	2·9	4·3	1·4	1·8	1·8	104·7
Green ..	5·1	10·6	1·0	1·4	1·5	2·5	1·4	2·1	2·5	116·1
Red ..	5·9	12·0	0·8	1·2	1·5	2·4	1·4	2·1	2·4	130·2
White ..	5·9	10·7	0·7	1·2	1·1	1·9	1·7	2·3	2·5	131·8
L.S.D. at P=0·05	0·57	1·36	0·18	0·38	0·37	0·38	0·26	0·32	0·26	16·65

The dry weights of ten plants in each treatment were determined after 26 days. Maximum dry matter accumulation occurred in red and white light ; the dry weight in green was greater than in blue, but not significantly so, the energy level in green being, however, 11 per cent. lower.

RESULTS WITH *Lycopersicon esculentum.*

A. Mean energy level 3,136 ergs/cm.²/sec. ± 170·2. Range 2,730-3,505.

Seeds of the varieties Early Market, Potentate and Ailsa Craig were sown on 10.6.52 and transferred to a 17-hour day in the compartments on 3.7.52 when the plants selected were approximately 4 cm. tall. The mean temperature range was 65-75° F. Since the energy level was too low for the plants to grow well, half the number of plants in each chamber were sprayed with a solution of sucrose. In each compartment the 36 plants (6 replicates × 3 varieties × 2 spray treatments) were arranged in a latin square design. The sucrose was applied as a solution of 10 per cent. sucrose, 0·025 per cent. sulphonamide and 0·1 per cent. spreader (Went and Carter, 1948), the plants being sprayed fourteen times during the experimental period. The plants were harvested after five weeks in the compartments.

There was a marked difference in the type of growth made in the different wave-length regions. In the red compartment growth was abnormal : the plants were very tall, with long internodes, and there was pronounced epinasty of petioles and leaf blades, the latter being completely rolled under. In the blue compartment there was no leaf epinasty ; the petioles made an acute angle with the stem and the leaf blades were flat. The non-sprayed plants under this light treatment made almost no growth ; the leaves were small and very thin and the stems slender. In the green compartment there was some epinasty, particularly of the younger leaves, but this was less pronounced than in red. The plants in white light were normal in appearance, considering the low energy levels at which they were grown ; the stems were thicker than in the other treatments and the leaf area was greater.

No qualitative differences were observed between sprayed and non-sprayed plants. The effect of the sugar spray was to increase each expression of growth (i.e. height, weight, internode length, and length and width of the leaves) by approximately the same amount in each light treatment (Fig. 1). Under the blue light growth without added sucrose was so poor that some measurements could not be made.

The three varieties showed a marked difference in their ability to grow under the conditions of the experiment. Early Market was greatest in fresh and in dry weight and in total stem length. Potentate was greater than Ailsa Craig in fresh and in dry weight but not in total stem length. No qualitative differences in the formative effects of the different wave-lengths of light on the three varieties were observed.

The effects of the light treatments on stem elongation and leaf expansion can be summarized as follows. The total stem length and internode length were increased at longer wave-lengths. The internode length in the white compartment was the same as in the green, but the plants were taller because more leaves had developed. The length and width of the leaves also increased with increase in wave-length. The mean values for sprayed and non-sprayed plants are given in Fig. 1.

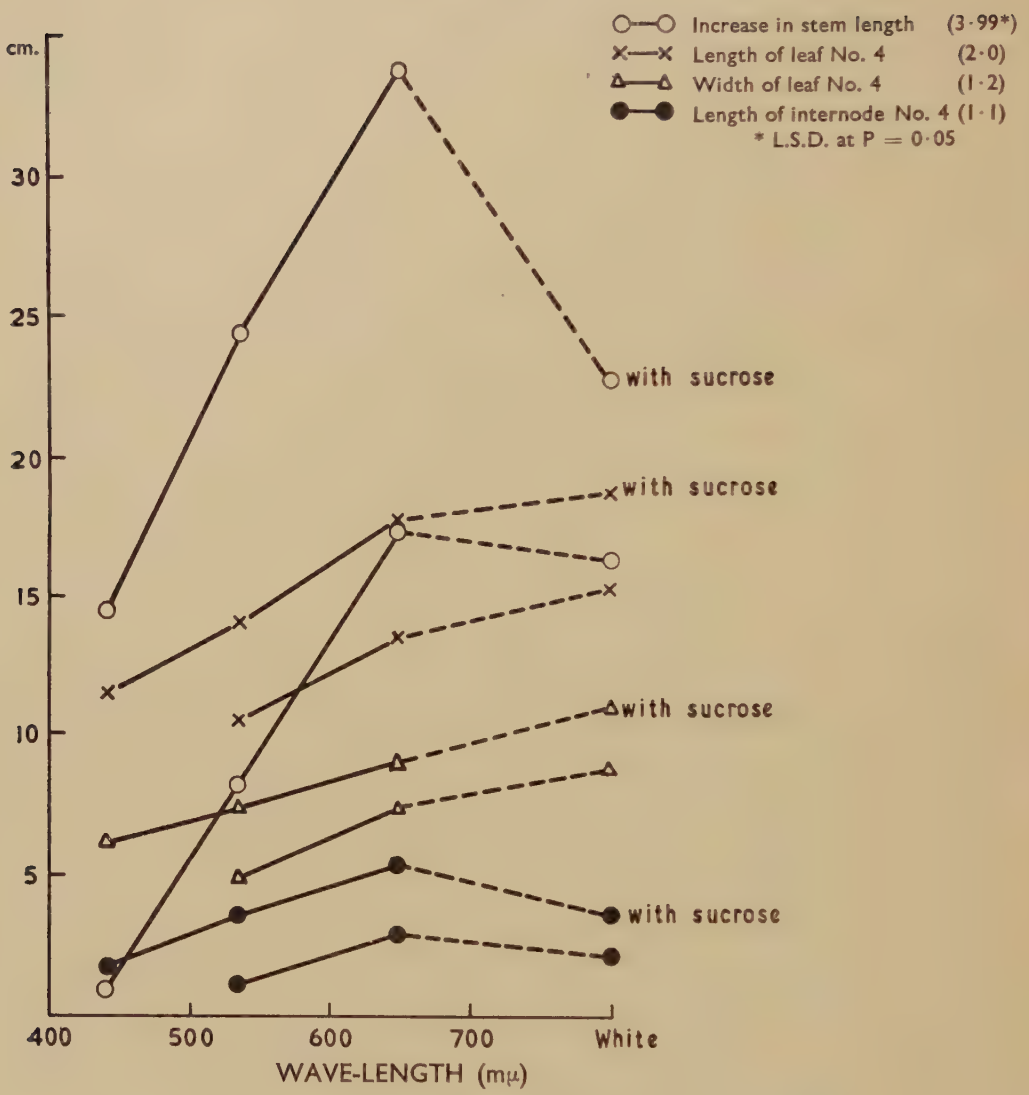

FIG. 1.

Effect of quality of light on growth of *Lycopersicon esculentum*.

B. Mean energy level 7,345 ergs/cm.²/sec. ± 39·9. Range 7,369-7,451.

Seed of the variety Early Market was sown on 8.7.53, and transferred to the light compartments on 24.7.53, when two small leaves were present. The plants were maintained in a 17-hour day, with a mean temperature range of 60-67° F. Four plants from each light treatment were sampled and measured at weekly intervals. The appearance of the plants was similar to that in the previous experiment. Those under the red and white lights made the most rapid growth, whereas in the blue and green compartments the plants had very slender stems and thin, small leaves. Leaf

curling and abnormal elongation of the stems in red light were noticeable by the fourth week of the treatment. The measurements for the final samples, nine weeks after the beginning of the treatments, are given in Table III.

TABLE III.

Effect of wave-length of light on growth of Lycopersicon esculentum *Early Market, after nine weeks of light treatment. Mean energy level—7,345 ergs/cm.²/sec.*

	Total stem length (cm.)	No. leaves	Internode length (cm.)			Leaf length (cm.)		
			1	2	Mean*	3	4	5
Blue	25·0	7·3	1·4	5·7	3·4	12·8	13·5	13·6
Green	29·9	7·3	2·9	6·5	4·1	13·7	13·9	13·3
Red	69·8	12·3	1·9	7·6	5·7	21·0	25·1	27·1
White	35·1	10·3	1·8	4·0	3·4	23·0	24·8	27·1
L.S.D. at P=0·05 ..	9·20	1·78	—†	0·94	0·60	2·77	3·43	3·65

* Mean of all internodes.
† Difference not significant.

Increases in wave-length resulted in increases in total stem length, internode length and leaf length, but the differences between blue and green were small compared with those between green and red. Epinasty and leaf rolling occurred at wave-lengths greater than 500 mμ, but were most marked at wave-lengths greater than 600 mμ.

The dry weights of the samples taken at intervals over the nine-week period (Table IV) were found to increase most rapidly in red light. The minimum dry weights occurred in blue and green. In white light the dry weight did not differ significantly from that in red, even though the expanded leaf surface was much reduced in the latter.

TABLE IV.

Effect of wave-length of light on total dry weight (mg.) of Lycopersicon esculentum *Early Market at intervals over a nine-week period. Mean energy level—7,345 ergs./cm.²/sec.*

Date of Sample	July 29	Aug. 12	Aug. 19	Aug. 26	Sept. 2	Sept. 9	Sept. 16	Sept. 23
Blue	21	26	39	55	73	152	151	228
Green	17	22	50	69	89	177	212	227
Red	23	45	118	205	361	678	1,323	2,020
White	13	58	148	249	356	855	1,365	1,902
L.S.D. at P=0·05	not determined							469

DISCUSSION.

It is apparent that different species, and even varieties of the same species, do not respond in the same way when grown under similar conditions in light of different wave-lengths. Earlier experiments on the effect of wave-length of light on the growth

of plants may be broadly divided into two groups. In one the visible spectrum has been divided into regions of high spectral purity and often of narrow wave-band width, which has resulted in low energy levels or small irradiated areas and led to the choice of certain seedlings for experimental work. Many of these experiments have been carried out in strictly controlled conditions and action spectra have been determined for internode and leaflet length in *Pisum* (Parker *et al.*, 1949) and mesocotyl length in *Avena* (Goodwin and Owens, 1948). Experiments of this kind have shown that internode elongation in *Pisum sativum* Little Marvel and *Phaseolus vulgaris*, and mesocotyl and internode elongation in *Avena* and some other grasses decrease with increase in wave-length of the incident light. Leaflet expansion in both *Pisum* and *Phaseolus*, however, increased with increase in wave-length, minimum expansion occurring in green in some experiments (Went, 1941 ; Parker *et al.*, 1949). In the other group of experiments, where light of less restricted wave-length regions has been used, higher energy levels or a greater area irradiated have permitted the growth of a wider range of species. Most of the experiments prior to 1930 fall into this latter group, and from them it was concluded that, in general, total stem length and internode length were increased at longer wave-lengths.

It seems likely that many of the differences observed may be due to variation in the response of the species grown, rather than to differences in experimental technique or in the composition of the light sources since, in the present experiments, tomato and pea grown under the same light sources did not respond to wave-length in the same manner. In tomato, the total stem length and internode and leaf lengths were greatest in red light. In Meteor pea, the internode length was greatest in blue light but the leaflet length increased with increase in wave-length. In the majority of species grown previously in light of restricted wave-lengths, internode and stem length have been shown to increase at longer wave-lengths ; the only organs for which decrease in length in the orange/red region of the spectrum has been reported are the internodes of pea and bean, and mesocotyl and internodes of some grasses. The effect of wave-length of light on growth of pea reported for the variety Little Marvel and observed here in Meteor does not occur in all varieties. In Alaska, grown under the same conditions as Meteor, there was little difference between plants in any wave-length region.

Both species showed downward curling of the leaves in red light, and this effect was particularly marked in the tomato. Tomato plants grown under red tubes without the pigment coating did not show leaf epinasty. Since in other respects the lamps were identical, the difference in growth behaviour of the plants was due to the presence or absence either of the mercury blue lines or of the continuum below 600 mμ. Some leaf curling occurred when the plants were grown in green light (500-600 mμ) and it is, therefore, probable that the radiation in the mercury blue lines (365, 405 and 436 mμ) modified the growth behaviour of the plants grown under the non-pigmented red lamps. The light-sensitive system concerned must react to relatively small amounts of blue/violet radiation, seeing that the energy present in the mercury blue lines is only 12 per cent. of the total light radiated from the unpigmented red lamps.

Maximum dry matter accumulation occurred in red and white light in both species ; under similar experimental conditions maximum dry weight accumulation in red light has been reported for *Cosmos bipinnatus* by Wassink and Stolwijk (1952) and for *Tradescantia fluminensis* by van Schoor (1942).

SUMMARY.

When grown in light restricted to one of three broad divisions of the visible spectrum, the two species *Lycopersicon esculentum* and *Pisum sativum* responded differently. When the plants were grown at equal incident energy levels in each spectral region, total stem length, internode and leaf length increased in *Lycopersicon* with increases in wave-length ; in *Pisum* var. Meteor total stem length and internode length decreased, and leaflet length increased, with increases in wave-length. In *Pisum* var. Alaska there was little difference in plants from any wave-length region. It is pointed out that, in the majority of species which have so far been grown in light of restricted wave-lengths, the response is the same as shown here in *Lycopersicon*.

Plants grown in light of wave-lengths above about 500 mμ, and particularly the tomato, showed leaf epinasty, this being most marked at wave-lengths above 600 mμ. In light of wave-lengths less than 500 mμ the leaf blades were flat. The energy of the mercury blue lines in unfiltered red lamps was sufficient to prevent leaf-rolling in tomato.

The total dry weight of plants was greatest in red light and in the complete spectrum, and least in green and blue light.

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(*Received* 26/2/55.)

BORON NUTRITION OF THE HOP*

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SOME continental workers have suggested that boron is an important element in the nutrition of the hop. Doerell (1933) cites Torring as stating, as long ago as 1769, that it was a popular belief that hops would grow well on land favoured by wild sloes and crab apples, and Bertrand (1942) found a similar association between hops and hemlock, another boron-rich plant. Zattler (1942) quotes a case where sugar beet, growing in a recently grubbed hop garden in the rows where the hops had previously been, showed symptoms of " heart-rot "—a condition due to lack of available boron—whereas beet growing between the previous hop rows were quite healthy. The boron content of the soil of this affected garden was shown to be much lower than that of soils on which heart-rot in sugar beet did not appear and Zattler concluded that the growing of hops had impoverished the soil of boron.

Linke (1938) in Czechoslovakia, Elsocht and Hoed (1939) and Hoed (1942) in Belgium carried out many trials using comparatively small applications of borax to hop soils, and sometimes found that the yield and resin content of the hop were increased.

No symptoms which could be definitely ascribed to boron deficiency in hops had been noted up to 1950 and in south-east England no suspected instances had been seen or reported. Nevertheless, as it had been suggested that applications of boron might increase the yield and resin content of the hop, and since a slight deficiency of boron might be " symptomless " or pass unrecognized in the field, it was considered that an investigation of the boron nutrition of the hop might well be undertaken. Work was therefore begun along the following main lines :

1. Varietal and seasonal variations in the boron content of the hop leaf;
2. Effect of cutting the bines at picking time on the boron content of the rootstock;
3. Production in sand cultures of symptoms of boron deficiency and toxicity in the hop ;
4. An examination of suspected boron deficiency in hops in the West Midlands.

1. VARIETAL AND SEASONAL VARIATIONS IN THE BORON CONTENT OF THE HOP LEAF.

EXPERIMENTAL METHOD.

In 1950 and 1951, an experiment was carried out in Silks Hop garden at Wye College with Eastwell Golding and Early Bird hops to study the variation in the mineral content of hop leaves with variety, position on the bine and date of sampling. The layout of this experiment and the results obtained for nitrogen, phosphorus, potassium, calcium, magnesium and manganese have been fully described by Watson (1952).

* This paper is a report of the work carried out at Wye College as a partial requirement for the M.Sc. degree of the University of London.

The following standard leaves were sampled throughout the season and their boron content determined by the Alizarin Blue method (Trinder, 1948) :

Leaf A or " Top Leaf " : the first pair of open young leaves below the growing-point ;

Leaf B or " Youngest Fully Expanded Leaf " : the lowest fully expanded leaf to retain " bloom " on its surface, all lower leaves being of harsher texture and slightly darker in colour ; generally 3-6 nodes below the " Top Leaf " ;

Leaf C or "Fixed-Height Leaf " : the leaf at the height of the tie-in string, $4\frac{1}{2}$ ft. from the ground.

RESULTS.

Since varietal differences in the leaf boron content were very small, only the results for Eastwell Golding leaves sampled in 1950 are discussed below. These, calculated on an oven-dry basis, are presented in Fig. 1.

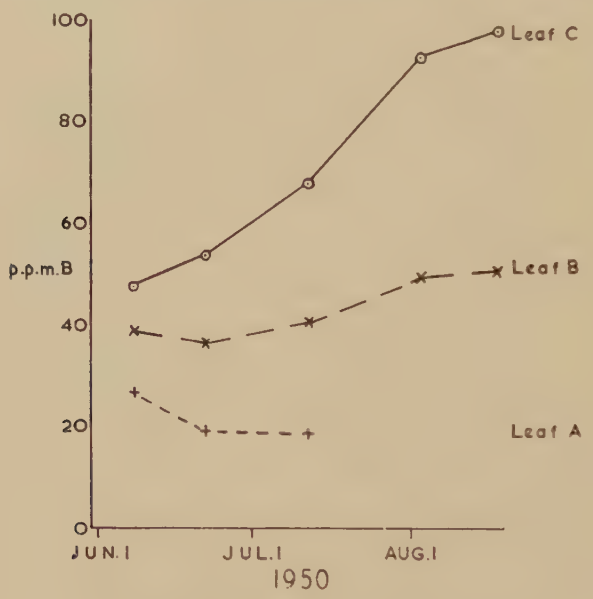

FIG. 1.

Variation in the boron content of hop leaves.

On every sampling occasion the boron content of the less mature leaves was significantly lower than that of the more mature ones, i.e. A < B < C, and this difference increased with age.

The boron content of Leaf A decreased significantly early in the season and then remained constant at a comparatively low level (about 20 p.p.m. boron*). The boron content of Leaf B increased from the end of June onwards, but this increase

* p.p.m. boron mentioned here and elsewhere in the text refers to total boron expressed on a dry matter basis for vegetative tissue or water-soluble boron in air-dried soils, unless otherwise stated.

was statistically significant only from early July to early August when the content rose from 40·2 to 49·2 p.p.m. boron. The boron content of Leaf C increased steadily throughout the season but this increase was statistically significant only between late June and early August when the content rose from 53·5 to 92·5 p.p.m. boron.

In the early part of the season, while the hop plants are growing vigorously, Leaf A samples represent actively developing leaves and Leaf B samples those that are just fully developed but showing no signs of senescence. Leaf C samples, on the other hand, are mature and become increasingly senescent with successive samplings. These results show that the boron content of a leaf increases with age.

In normal advisory work the " Youngest Fully Expanded Leaf " (Leaf B) is generally taken for the determination of the major elements. This procedure would appear to be satisfactory for boron determinations ; but it must be emphasized that, if a comparison is to be made between healthy and affected plants, the samples taken must be of similar age.

2. BINE CUTTING EXPERIMENT.

A randomized experiment was laid down at Wye in 1950 on three varieties of hop, viz. Early Bird, Petham Golding and Eastwell Golding, planted in 1949, to determine the effect of cutting the bines at picking time on the future cropping and nutrient status of the plant.

No significant differences in yield due to cutting the bine at picking time were found in 1951 or 1952, the growth in all plots being very vigorous in all seasons (Burgess 1952, 1953).

In 1951, samples of whole bines cut at picking time and whole bines cut after a period of ripening on the plant were taken from all three varieties and their boron content determined by the Alizarin Blue method.

The results of these analyses are presented below:

Variety	p.p.m. boron in oven-dry bine	
	Cut at picking time	Cut after ripening
Early Bird	16·4*	16·9*
Eastwell Golding	17·8	17·5
Petham Golding	19·4	19·0

* Means of four replicate samples.

While the above data suggest a varietal difference in the boron content of both types of bines, the variations within each treatment were not significant. In each of the three varieties there was little difference between the boron content of bines cut at picking time and after ripening. This suggests that boron does not return from bine to rootstock during this period and in this respect its behaviour is similar to that of calcium (Burgess, 1949).

The average yield of kiln-dried hops in England in 1953 and 1954 was 12·4 cwt. per acre, which is equivalent to 11·2 cwt. of moisture-free hops per acre, assuming that kiln-dried hops contained 10 per cent. moisture. Hall (1901) states that, in an average crop, the ratio of cones : bine : leaves is about 1·5 : 1·3 : 1 on a dry

matter basis. Thus it can be calculated that the actual weight of cones, bines and leaves produced per acre is about 1,250, 1,090, and 840 lb. dry matter respectively. It has been found at Wye that the average boron content of these materials is about 30, 15 and 50 p.p.m. boron on a dry matter basis respectively ; thus their boron content would be about 0·6, 0·25 and 0·7 oz. boron per acre, which is equivalent to 5·3, 2·3 and 6·0 oz. borax per acre.

The cones are removed from the garden each year whatever method of picking is adopted. The boron in the bines has been shown not to return to the rootstocks but an appreciable amount of it might be retained if the bines were composted or burnt at a fairly low temperature and so returned to the garden. Many leaves would drop in the garden during the growing season and be decomposed in the soil and their boron content released : the rest would be composted or burnt with the bines. The annual loss of boron in the cones, though small, might in time lead to boron deficiency in hops grown continuously in soils of a poor boron-supplying status, such as those in parts of the West Midlands.

3. SAND CULTURES.

Experimental method.

This experiment was carried out over the seasons 1951-53, using horticultural clay pots treated inside with bitumen paint. Two strap cuts of clonal Fuggle N hops were planted in acid-washed sand in each of 27 pots on the 15th April, 1951. Random samples of these cuttings had been analysed previously and found to contain about 13 p.p.m. boron. Nine treatments, consisting of combinations of three levels of boron with three levels of calcium, were given in triplicate. These treatments were applied as solutions and, in addition, each pot received the same quantity of other essential elements, viz., nitrogen, phosphorus, potassium, magnesium, iron, manganese, zinc, copper and molybdenum.

The growth of the plants was recorded each season. The " Youngest Fully Expanded Leaves " from each treatment were sampled in mid-July and mid-August. The hops were picked early in September and samples of the bines, between the 5th and 8th nodes from sand-level, were taken shortly after this. The hop cones were weighed after picking and the leaves, bines and cones were dried, ground and analysed for boron, calcium, magnesium, potassium, phosphorus, iron and manganese. At the end of the 1953 season the terminal six inches of bine and the roots were similarly examined.

In 1951, the treatments applied were :

Treatment	p.p.m. in nutrient solutions										
	B	Ca	N	P	K	Mg	Fe	Mn	Zn	Cu	Mo
Low	*nil**	20	290	40	80	40	5	0·3	0·05	0·05	0·015
Medium ..	0·5	100									
High	10·0	500									

* No boron was given in the " low " boron treatments, but it is possible that the acid-washed sand contained a trace of boron. Similarly, the chemicals used in the nutrient solutions, although of Analar grade, may have contained some boron.

At the end of the 1951 season it was obvious that the high level of boron was very toxic and that the low level of calcium was inducing calcium deficiency. In consequence these treatments were modified and, in addition, the level of potassium was raised for all treatments, as slight symptoms of potassium deficiency had appeared. The revised treatments applied in 1952 and 1953 are given below :

Treatment	p.p.m. in nutrient solutions										
	B	Ca	N	P	K	Mg	Fe	Mn	Zn	Cu	Mo
Low	*nil**	100	300	40	200	40	5	1	0·05	0·05	0·015
Medium ..	0·5	200									
High	1·0	300									

* As on preceding page.

As no symptoms of boron toxicity developed in the plants receiving 1 p.p.m. boron, a further small experiment was carried out in sand culture in 1954, giving treatments of *nil*, 1 and 2 p.p.m. boron, with three replications. In this experiment the calcium level remained constant at 300 p.p.m. and the other nutrients were supplied in the amounts given in 1952 and 1953.

Results.

In 1951, all plants receiving 10 p.p.m. boron showed symptoms of boron toxicity about six weeks after the sets had been planted. The leaves developed chlorosis, particularly around the margins, and curled downwards with poor differentiation into lobes. Brown spots about 1 mm. in diameter developed interveinally as the leaves aged. These spots were more numerous towards the leaf margins, where scorching developed together with a tendency for the margins to curl upwards in contrast to the downward curling of the leaf as a whole (Fig. 2). The leaf became progressively more chlorotic, though the veins remained dark green. The scorched area developed from the margin inwards and the leaf eventually died. Stipules, which were originally a healthy green colour, became progressively scorched from the tip to the base as they aged. The growing points of the main bines and laterals were not visibly affected. The symptoms of boron toxicity observed were similar in all plants receiving 10 p.p.m. boron at all levels of calcium supply.

Cones were produced in all treatments but were small and few in number, particularly those from plants receiving the 10 p.p.m. boron and 500 p.p.m. calcium treatment.

No pronounced symptoms of boron deficiency were observed in 1951 but the growing points of some plants receiving no boron wilted and died.

Marked symptoms of boron deficiency appeared early, both in 1952 and 1953, in plants receiving no boron, first in those plants receiving high calcium and later in those receiving medium calcium (Fig. 3). The rootstocks generally produced many shoots with short internodes (about $\frac{1}{2}$ in.). The growing points turned brown and died, sometimes when the shoots were only a few inches high (Fig. 4). Further shoots were produced, most of which died in a similar manner, thus giving a bushy appearance to the plant. Some later-formed shoots survived longer but these generally died back from the growing point downwards while still fairly short. Many lateral buds on the main shoots turned brown and died without developing. Stunted laterals with very short internodes were developed on the

surviving main shoots ; these laterals also eventually died back (Fig. 5).

The first leaves were very small and their margins slightly chlorotic. The stipules were green when first produced but rapidly became scorched, progressively from the tip downwards, as they became older. Some of the leaves produced later in the season were also small and frequently not lobed, and were distorted and deeply toothed. This latter tendency was more marked from the end of June, 1953, particularly in the low boron—low calcium series, in which the symptoms were very similar to those of " ivy leaf ", a leaf abnormality sometimes observed in the field. Some leaves in the low boron—high calcium series were not serrated at all but puckered and distorted with the margins curled back underneath, though without any necrosis.

Towards the end of July, 1953, some bines receiving no boron showed symptoms very similar to those of " fluffy-tip " as described by Keyworth (1945). The upper 6 in. or so of the bines had rather short internodes and tended to remain straight and stand away from the string. The upper four pairs of leaves remained small, their stipules were larger than usual and were held at right angles to the bine. These stipules were pale green and had a pinkish tinge which was darker nearer the bine.

The plants that received no boron produced some burr, but this hung a long time before being fertilized and many inflorescences turned brown and died. Cones that developed were loose and small (about $\frac{1}{2}$ in. long), and the bracts frequently showed scorching beginning at the tip and progressing to the base ; the bracts tended to be reflexed. The total crop produced was very small.

At similar rates of calcium supply, there were very small differences between plants receiving 0·5 p.p.m. and 1·0 p.p.m. boron in growth, in mineral content (excluding boron) of leaves, cones, bines, "shoots" and roots, in fresh weights, and in total soft resin and " alpha acid " content of the cones.

At the end of the 1953 growing season the terminal 6 in. of bine was taken for analysis. This showed that " shoots " from the plants which received no boron contained only about 17 p.p.m. of the element, whereas " shoots " from boron treated plants contained over 27 p.p.m.

At the end of 1953 the root systems of plants receiving no boron were poorly developed as compared with those of plants that had received boron (Fig. 6). Many rootlets of the former had died at various stages of development.

In the 1954 experiment, plants receiving no boron developed symptoms of boron deficiency as described above. Those receiving 2 p.p.m. boron grew normally and showed no signs of boron toxicity.

Discussion.

The above results suggest that boron is essential for the adequate growth of the hop, and confirm the results of Askew and Monk (1951, 1953) in New Zealand.

The fact that marked symptoms of boron deficiency did not appear until 1952 in hops growing in acid-washed sand suggests that the strap cuts planted in 1951 contained sufficient boron for their initial growth. Analysis showed that boron was translocated to the bines, leaves and cones during the growing season but did not return to the rootstock. The plant was thus depleted of boron by 1952 and symptoms of acute deficiency developed. This may be one reason why the replacement of hills, that have failed, with fresh sets from another garden may sometimes be beneficial.

The symptoms of " ivy leaf " that were observed in the plants receiving no boron have been seen occasionally in commercial hop gardens. In the field, they do not appear in the same plants in successive years and neighbouring plants may appear quite healthy. The symptoms are more prevalent in dry seasons. In the West Midlands, close examination of Fuggle plants in the field trial on boron deficiency discussed below showed that many plants had symptoms of " ivy leaf ". In the South-east, hop varieties of Manitoba parentage, such as Brewer's Gold and Bullion, develop these symptoms more frequently than others growing on the same soil, and no instance of these symptoms has been reported in Fuggle. Affected plants have quickly resumed normal growth and the condition has not been considered to be of economic importance.

The evidence suggests that " ivy leaf " may be due to boron deficiency and that some varieties, particularly those producing large amounts of resin, require more boron than others.

Although boron is essential for the growth of the hop, in these experiments a supply of 1 p.p.m. boron in the nutrient solution had no more effect than 0·5 p.p.m. on the weight of cones produced or their resin content. Levels of up to 2 p.p.m. boron were tolerated, but a supply of 10 p.p.m. boron was toxic.

4. SOIL INVESTIGATIONS.

Although boron deficiency in hops has not been observed in south-east England, in some yards (gardens) in the West Midlands where hops have failed to grow satisfactorily the plants have shown symptoms suggesting boron deficiency (Burgess, 1952, p. 10).

In 1952 a small experiment was laid down in a yard in Hereford where, in the Spring of 1951, the rootstocks produced many stunted shoots which died back from the growing point similarly to those in sand cultures with no boron added. The experiment comprised four rows, each of six hills, each of the 24 hills being treated with $\frac{1}{2}$ oz. borax mixed with $\frac{1}{2}$ lb. dry sand. The mixture was distributed as evenly as possible round the hills, early in May, 1952.

Analysis of soil samples taken from these rows immediately prior to the application of borax gave the following results :

Soil sample (0–6 in.)	p.p.m. water-soluble boron
Row 1	0·61
Row 2	0·54
Row 3	0·91
Row 4	0·66

These values are, in general, lower than those found in soil samples from hop gardens in the South-east. The figures for a range of such soils, developed on different geological formations, are given below :

Underlying geological material	p.p.m. water-soluble boron in top 6 in. soil
Lower Greensand	0·89, 1·51
Weald Clay	1·10, 1·49, 1·67
Hastings Beds	0·77, 0·84, 0·98, 1·07

Analysis of soil samples from the field trial in Hereford taken at the end of August, 1952, from untreated rows and from the borax treated rows, gave the following results :

Soil sample (0-6 in.)	p.p.m. water-soluble boron
Untreated rows	0·74
Borax treated rows	1·14

These results show that the application of borax in May, 1952, has increased the water-soluble boron in the soil.

Samples of "Fixed-Height Leaves" and of cones were taken on 26th August, 1952, and their boron content determined :

Sample		p.p.m. boron in oven-dry material
"Fixed-Height Leaves" from	untreated hills	79·8
	borax treated hills	122·4
Cones from	untreated hills	24·3
	borax treated hills	27·3

It was clear that boron applied to the soil was taken up by the plants, and there was no indication that a dosage of ½ oz. borax per hill was toxic. As had been found previously at Wye, the boron content of the cones was much lower than that of the "Fixed-Height Leaves" from the same plant at the same time ; nevertheless a slight difference in favour of the borax treatment appeared in the cones.

Samples of the "Youngest Fully Expanded Leaves" were taken from the untreated and borax treated hills in July, 1953, and analysed for boron with the following results :

Sample	p.p.m. boron in oven-dry material
Leaves from untreated hills	13·0, 15·0
Leaves from borax treated hills	17·3, 20·5

These results show that borax applied to the soil in May, 1952, was still present in the soil in a form available to the hops about a year later. The original symptoms have not so far reappeared in the borax treated plots, but symptoms associated with boron deficiency have continued to appear sporadically in the untreated rows.

As can be seen from Fig. 1 the boron content of "Fixed-Height Leaves" (C) in August, taken from hops growing on a deep loam at Wye, is about 90 p.p.m., so that the figure given above (79·8 p.p.m. boron) for the morphologically similar leaves from untreated plants at Hereford, though lower, is of a similar order. This may be associated with the marked accumulation of boron that occurs in "Fixed-Height Leaves" as is shown in Fig. 1. In the "Youngest Fully Expanded Leaves" (B), such an accumulation does not take place and it is of interest that such leaves from the Hereford hops show much lower boron contents than the morphologically comparable leaves from plants at Wye.

PLATE I

Fig. 2.

Boron toxicity in hops. Leaves arranged in age sequence from top left (youngest) to bottom right (oldest).

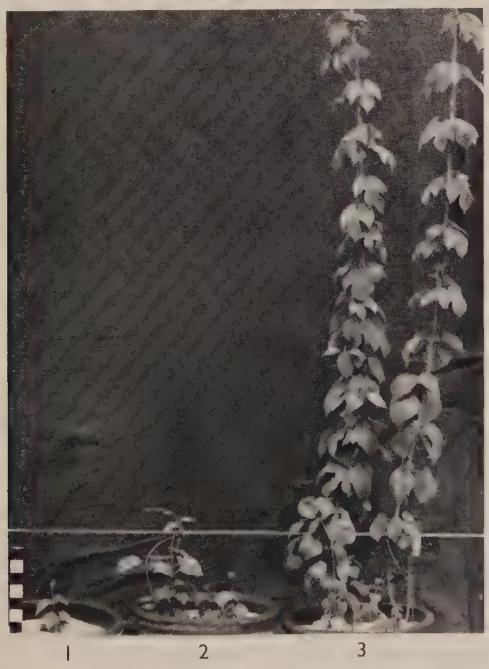

Fig. 3.

Boron deficiency in hops in sand cultures. Pots 1 and 2 received no boron and pot 3 received 0·5 p.p.m. boron in the nutrient solutions.

[*face p. 32*

FIG. 4.

Boron deficiency in hops in sand cultures receiving no boron, showing stunted shoots and distorted leaves.

FIG. 5.

Laterals from similar positions on plants growing in sand cultures. Laterals 1 and 2: normal nutrients, no boron, showing dying growing points, short internodes and distorted leaves. Lateral 3: normal nutrients + 1 p.p.m. boron.

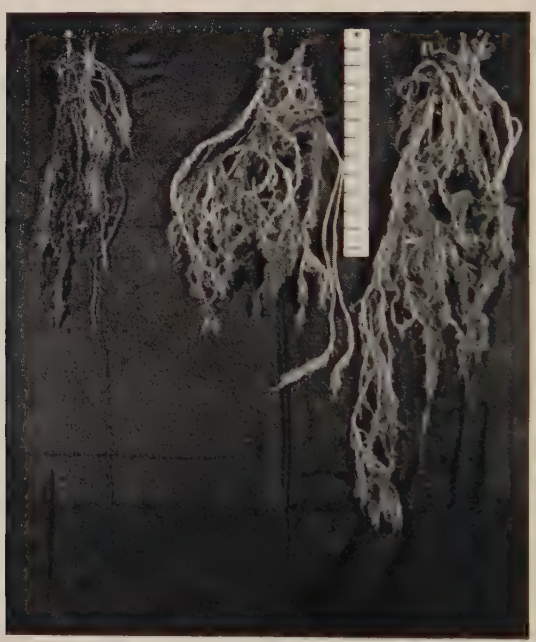

FIG. 6.

Root systems of hops which had received 0, 0·5, and 1 p.p.m. boron in the nutrient solutions (left to right).

SUMMARY.

1. The boron content of hop leaves increases with maturity.

2. Boron does not return from the bines to the rootstock on ripening.

3. Symptoms of boron deficiency in hops growing in sand-cultures are described, and this condition has been shown to be accentuated by high calcium treatment.

4. A supply of 0·5 p.p.m. boron in the nutrient solution was adequate for normal growth of hops growing in sand cultures.

5. Symptoms of boron toxicity in sand cultures, which are described, were not developed in hops receiving up to 2 p.p.m. boron in the nutrient solution, but appeared in hops receiving 10 p.p.m. boron.

6. An account is given, with supporting soil and plant analytical data, of a field trial in a hop yard in Hereford, where plants showing symptoms corresponding to those found with boron deficiency in sand culture responded to treatment with borax.

ACKNOWLEDGMENTS.

The author is indebted to Prof. R. L. Wain who supervised, in part, the studies reported above and assisted in the preparation of this paper. He also wishes to express his sincere thanks to Messrs F. C. Thompson and G. A. Watson for their valuable advice, criticism and assistance during the course of this investigation, and to Mr. G. P. Chater of the N.A.A.S. for supervising the soil experiments and for collecting soil and leaf samples from the West Midlands. The assistance of Mr. E. J. Chittenden in the collection of samples and their preparation for analysis is also acknowledged.

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(*Received* 17/3/55.)

PREDACIOUS SPIDERS IN ORCHARDS IN SOUTH-EASTERN ENGLAND*

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EXCEPT for the work of Bristowe (1939) in the biological, and of Locket and Millidge (1951) in the systematic field, comprehensive studies of spiders have rarely been undertaken. Few attempts have been made to assess their importance in controlling specific pests and, apparently, none of these has been concerned with the insects and mites attacking fruit trees. This situation is surprising because virtually all spiders are completely predacious. The author's interest in predacious spiders was stimulated by the unpublished work of Turnbull (1953) who investigated the effects of spiders on the Spruce budworm, *Choristoneura fumiferana* (Clem.), in Western Canada.

The opportunity of examining the influence of the spiders inhabiting orchards in the counties of Kent and Essex in 1952-55 was taken in the course of a study of the Laelaptid mites predacious on the Fruit Tree Red Spider Mite (*Metatetranychus ulmi* (Koch)) and the Bryobia Mite (*Bryobia praetiosa* Koch) in these situations. Papers dealing with other predators of these mites such as Mirids, Anthocorids, and mites of the genus *Typhlodromus*, have appeared in recent years (Collyer, 1952, 1953a and b ; Pickett *et al.*, 1946 ; Kuenen, 1947 ; Lord, 1949 ; Clancy and Pollard, 1952 ; and others) but spiders appear to have been overlooked, the literature in this regard consisting of remarks in four papers that spiders appear to feed on various members of the family *Tetranychidae* (Klein, 1936 ; Kanervo, 1938 ; Kuenen, 1941 ; Listo *et al.*, 1939).

This paper reports general information obtained concerning the complex of spiders found in orchards, and the feeding of these on injurious species, and particularly on phytophagous mites. It is hoped that workers concerned with investigations of orchard fauna will in future include spiders among the predators to be studied.

METHODS.

1. *Sampling*. Spiders were collected by tapping a branch sharply several times with a slender stick. A beating tray, into which the dislodged spiders fell, was held under the branch. When samples were taken for comparative purposes, every effort was made to beat the same amount of branch for each.

2. *Rearing*. For feeding studies with smaller spiders, rearing was done in petri dishes of various sizes. Larger ones were reared either in 3 in. glass tubes or in wooden cages 4 in. × 4 in. × 3 in. fitted with gauze sides and a front of acrylic sheeting. Rearing was done either on single leaves or on leafy spurs with the bases projecting through the bottoms of the cages into moist sand.

3. *Collecting*. Specimens were collected into 70 per cent. alcohol to which had been added a small amount of glycerine. For identification of specimens the keys devised by Locket and Millidge (1951) were used.

* These studies were carried out during a period of residence at East Malling Research Station, Kent, England.

SPECIES CONCERNED.

During the three years of this study, many collections of spiders were made both in sprayed and unsprayed orchards. A list of the species found to occur in these places follows, with those known to feed on *M. ulmi* and *B. praetiosa* marked *.

An indication has been given of the habitat in which each species is usually found. Spiders from such places as swamps or on reeds probably occur fortuitously in orchards as a result of the vagaries of migration. Others from moss and debris probably are true inhabitants of the lichen- and alga-covered bark of unsprayed fruit trees.

SPECIES IN SPRAYED ORCHARDS.

OPILIONES
**Oligolophus agrestis* (Meade)

ARANEAE

Dictynidae :
Dictyna puella Simon (shrubs)
Argenna subnigra (O.P. Cambridge) (bushes)

Clubionidae :
Phrurolithus festivus (C. L. Koch) (debris)
Clubiona lutescens Westring (trees)

Thomisidae :
**Misumena vatia* (Clerck) (bushes)
Xysticus lanio C. L. Koch (trees)

Lycosidae :
Xerolycosa nemoralis (Westring) (woods)
Lycosa monticola (Clerck) (heathland)
Arctosa perita (Latreille) (heath, sand)

Theridiidae :
**Theridion pallens* Blackwall (trees)
Theridion vittatum C. L. Koch (trees)

Tetragnathidae :
Pachygnatha degeeri Sundevall (grass)

Argiopidae :
Zygiella x-notata (Clerck) (buildings)
Araneus diadematus Clerck (trees)
**Araneus cucurbitinus* Clerck (trees)
Meta segmentata (Clerck) (trees)
Theridiosoma gemmosum (L. Koch) (bushes)

Linyphiidae :
**Bathyphantes gracilis* (Blackwall) (bushes)
**Erigone dentipalpis* (Wider) (universal)
Agyneta conigera (O. P. Cambridge) (bushes)

SPECIES IN UNSPRAYED ORCHARDS.

Those also recorded in sprayed orchards are marked †.

OPILIONES
†**Oligolophus agrestis* (Meade)

ARANEAE

Dictynidae :
Lathys humilis (Blackwall) (bushes)
†*Argenna subnigra* (O. P. Cambridge)

Dysderidae :
Dysdera erythrina (Walck.) (rubbish)

Clubionidae :
Clubiona terrestris Westring (trees)
Clubiona brevipes Blackwall (trees)
Clubiona compta C. L. Koch (trees)

Thomisidae :
Xysticus kochi Thorell (bushes)
†*Xysticus lanio* C. L. Koch
†**Misumena vatia* (Clerck)

Salticidae :
Ballus depressus (Walck.) (trees)

Theridiidae : †**Theridion pallens* Blackwall
Theridion tinctum (Walck.) (low trees)
†*Theridion vittatum* C. L. Koch
Theridion instabile O. P. Cambridge (low plants)
Theridion pictum (Walck.) (bushes)
**Theridion ovatum* (Clerck) (low bushes)
**Theridion varians* Hahn (trees)

Tetragnathidae : *Tetragnatha montana* Simon (trees)
Tetragnatha pinicola L. Koch (trees)
**Tetragnatha extensa* (L.) (bushes)
†*Pachygnatha degeeri* Sundevall

Argiopidae : **Cyclosa conica* (Pallas) (trees)
†**Araneus cucurbitinus* Clerck
Araneus redii (Scopoli) (low plants)
**Araneus gibbosus* (Walck.) (trees)
Araneus cornutus Clerck (reeds)
Araneus umbraticus Clerck (bark of trees)
†*Theridiosoma gemmosum* (L. Koch) (bushes)

Linyphiidae : *Taranucnus setosus* (O. P. Cambridge) (swamps)
**Entelecara acuminata* (Wider) (trees)
**Moebelia penicillata* (Westring) (bark)
Micrargus herbigradus (Blackwall) (moss)
Gongylidiellum latebricola (O. P. Cambridge) (debris)
**Erigonidium graminicola* (Sundevall) (trees)
Ceratinella brevipes (Westring) (moss)
Wideria antica (Wider) (undergrowth)
Dicymbium nigrum (Blackwall) (undergrowth)
Meioneta rurestris (C. L. Koch) (trees)
Trachynella nudipalpis (Westring) (moss)
Cornicularia unicornis (O. P. Cambridge) (moss)
†**Erigone dentipalpis* (Wider)

The presence of one of these species, *Theridion pallens*, in orchards has already been noted (Massee, 1954).

A representative of the order OPILIONES has been included in this list because it is frequently abundant in orchards.

From sprayed orchards a total of 20 species, and from unsprayed orchards a total of 41 species have been collected. Undoubtedly these lists are not complete but they indicate the variety of Araneid fauna to be found.

The spiders shown as predacious on *M. ulmi* and *B. praetiosa* are not necessarily so at all stages in their development. Frequently, and particularly with the larger species, only the first one or two immature stages feed on the mites to any extent. Species which as adults feed on mites are confined almost entirely to the families Theridiidae and Linyphiidae.

ABUNDANCE IN ORCHARDS.

Usually spiders are rare in sprayed orchards until several weeks after the spray schedule has been completed. By that time, migrants are able to settle in the orchard

without being affected by toxic spray residues. A result of this migration is that the species occurring in commercial plantations are mostly those found in the woods and hedges immediately surrounding the orchards. On the other hand, many of the species found in unsprayed plantations seem to be indigenous to these, and frequently the species comprising the populations in the orchard and those in the surrounding hedgerows and copses are very different.

Most of the species listed above from sprayed orchards were collected in late summer or autumn after there had been ample opportunity for individuals to immigrate from the immediate surroundings. In unsprayed orchards, spiders are abundant throughout the year, many species even passing the winter in exposed conditions on the bark and twigs and apparently remaining active except on the coldest days (e.g. *Cyclosa conica*).

Some idea of the relative abundance of spiders in sprayed and unsprayed orchards may be obtained from Table I.

TABLE I.

Abundance of spiders in sprayed and unsprayed orchards, summers 1952-54.

Type of orchard	Locality	Number of beats	Total spiders captured	Number predacious on mites
Sprayed ..	Writtle, Essex	20	57	43
	Gt. Braxted, Essex	25	2	1
	East Malling, Kent	18	4	4
	East Malling, Kent	32	2	1
	East Malling, Kent	32	12	2
	Galleywood, Essex	100	60	24
	East Malling, Kent	50	3	1
	East Malling, Kent	32	15	8
Unsprayed ..	Penlan Hall, Essex	15	555	505
	Penlan Hall, Essex	20	242	203
	Ulcombe, Kent	16	66	60
	Ulcombe, Kent	20	112	112

These data can be summarized as follows :

Treatment	Total beats	Total spiders	Mean number per 10 beats	Number predacious on mites	% predacious
Sprayed	309	167	5·4	90	53
Unsprayed	71	975	137·3	880	90

Like other predators of orchard mites, spiders are much more numerous in unsprayed than sprayed orchards, and the opportunities for them to reduce mite populations must be greater under unsprayed conditions. Table II demonstrates the composition of populations occurring in sprayed and unsprayed orchards, and shows the development of these over a season.

Table II.

Analysis of populations in sprayed and unsprayed orchards.
(Numbers are for 60 beats.)

Family	Treatment						
	Sprayed			Unsprayed			
	Date			Date			
	June 15	July 7	Sept. 8	June 22	Aug. 17	Sept. 9	Oct. 19
Opiliones	0	3	0	9	30	42	0
Clubionidae	0	3	0	60	30	45	42
Thomisidae	0	2	0	15	30	33	42
Theridiidae	13	2	23	183	156	300	1,722
Tetragnathidae	0	0	0	15	0	75	102
Argiopidae	0	3	5	66	39	90	118
Linyphiidae	0	0	7	105	120	141	345
Total Arachnids	13	13	35	453	405	726	2,371

In unsprayed orchards, Tetragnathids were present on the trees only in the early summer and autumn, presumably during migration. Argiopids and Thomisids were present throughout the summer and increased slightly in number by autumn. Opilionids were found only in late summer and early autumn, whereas Theridiids were always present in moderate numbers ; the hatching of their eggs in late summer caused their numbers to increase greatly at that time. Linyphiids were also present throughout the summer in moderate numbers, and they also increased as a result of hatching late in the year. Apparently, this took place somewhat later than with Theridiids. The two families formed more than 80 per cent. of the spider fauna in unsprayed orchards. In some, Linyphiids are dominant types, with the numbers of Theridiids somewhat smaller. Apparently, the latter prefer orchards in sunny, warm locations, whereas Linyphiids occur mostly in dark, moist conditions.

In sprayed orchards (Table II) only Theridiids were present in early summer. Probably this was a result of the effect of winter washes, early insecticides and fungicides in eliminating the normal spider fauna. By the time the first sample was made this had been partially replaced by an influx of Theridiids, which migrate throughout the summer months (Bristowe, 1939). In mid-summer the population was low, probably because of further chemical treatment. Theridiids were again most numerous by the end of the season, and for the first time individuals of Linyphiidae were present, probably as a result of autumnal migration.

The small numbers of spiders obtained when collecting in sprayed orchards made it difficult to obtain significant results concerning the effects of specific chemicals. However, indications were obtained that chemical treatments have differential effects on a complex of species. Winter washes, lime sulphur, parathion, DPS, CPBS, and Ovotran appeared to reduce populations of all spiders. Whether this was always a result of direct chemical effects, or whether some spiders were removed from the trees by the mechanical effects of spraying, is not known.

FEEDING CAPACITY.

During the summers of 1953 and 1954 several experiments were conducted to investigate the feeding capacities and preferences of spiders from sprayed and unsprayed orchards. The first of these was conducted to determine the number of mites the various species were capable of destroying under conditions of low prey density (i.e. from 5 to 30 mites per leaf) ; in the same year the capacities of the same species were tested by providing a surplus of mite prey. The mites offered as food were *M. ulmi* and *B. praetiosa*, no distinction being made between them. Counts of the mites offered were made under conditions of low prey density, but this was not possible when larger numbers were being used. Table III shows a comparison of the capacities of various families under both conditions of prey density. The numbers of mites consumed were determined by counting the carcases of those upon which the spiders had fed.

TABLE III.

Feeding capacity of various spiders under conditions of both high and low prey density.

Prey density	Family	Number of spiders	Mean number mites offered	Mean number mites eaten	Mean number days	Mean number eaten per day
Low (5-30 mites per leaf)	Linyphiidae	4	99	36	39	0·9
	Theridiidae	5	123	60	56	1·0
	Argiopidae	3	50	17	15	1·0
	Thomisidae	1	30	18	7	2·5
	Clubionidae	1	69	43	45	0·9
	Opiliones	1	65	18	7	2·5
High (100+ mites per leaf)	Linyphiidae	9	400+	210	27	7·7
	Theridiidae	8	250+	134	17	7·8
	Argiopidae	4	200+	135	14	9·6
	Thomisidae	4	250+	152	18	8·4
	Clubionidae	1	100+	35	8	4·4
	Tetragnathidae	1	600+	323	39	8·2

The species tested during these experiments were as follows :

Linyphiidae : *Moebelia penicillata* adult and immature, *Micrargus herbigradus* adult and immature, and a variety of immature Erigoniid species.

Theridiidae : *Theridion pallens* adult and immature, *T. ovatum* immature, and a variety of immature Theridiid species.

Thomisidae : *Misumena vatia* immature.

Argiopidae : *Araneus cucurbitinus* immature, *A. gibbosus* immature, and *Cyclosa conica* immature.

Clubionidae : *Clubiona* spp. immature.

Opiliones : *Oligolophus agrestis* immature.

Under conditions of low prey density, spiders which had been left in the laboratory for the least number of days ate the largest numbers of mites per day. This may have been because freshly-caught spiders are somewhat more vigorous than ones which have been living under confined conditions for some time, and it should not be taken as a valid indication that those species invariably feed more heavily.

Obviously, spiders can maintain themselves at both high and low mite densities. Even at high densities the numbers of mites consumed per day is not large. However, spiders are active and live for a long time, as indicated by the numbers of days they were successfully maintained. Capsids and other insect predators of phytophagous orchard mites may consume more than 100 per day (Collyer, 1952) but this is for only a comparatively short time and usually takes place at the end of the season when mite densities in sprayed orchards are very high and damage to fruit trees may already have occurred.

VARIETY OF FOOD.

Little information concerning the feeding preferences of spiders is available. Bristowe (1939) has summarized what is known, most of the available information being based on experiments conducted by himself. He attempted to test the feeding of representatives of the major families of spiders on representatives of the chief orders of insects. His information concerning those insects and spiders of interest in the present context may be summarized as follows :

Hemiptera-Heteroptera : *Anthocoris nemorum* L. was rejected by *Dictyna arundinacea* L., *Araneus diadematus* L., *Zygiella* sp. and *Linyphia montana* L. *Orthotylus* sp. was accepted by *L. montana* and *A. diadematus* but rejected by *Zygiella* sp. *Campyloneura virgula* H.S. was accepted but not favoured by *L. montana*, and rejected by *Zygiella* sp. and *A. diadematus*. *Heterotoma meriopterum* Scop. was accepted by *L. montana* but rejected by *A. diadematus* and *Zygiella* sp. *Phytocoris tiliae* Fab. was rejected by *Zygiella* sp. and by *Clubiona* sp. *Deraeocoris ruber* L. was accepted by *Meta* sp. *Plagiognathus arbustorum* Fab. was accepted by *Dictyna arundinacea*. All these insects are considered to be predators of *M. ulmi* and *B. praetiosa* (Collyer, 1949). *Plesiocoris rugicollis* Fall., a pest of apple, was accepted by *L. montana* and *A. diadematus* but refused by *Zygiella* sp. Bristowe considers that most Hemiptera eject a fluid when attacked which causes the majority to be rejected by spiders.

Most Homoptera are acceptable to spiders but aphids and coccids are commonly rejected, as apparently the honey-dew they secrete is distasteful. In general, Bristowe's experiments show Homoptera to be accepted occasionally by Argiopidae, Theridiidae, and Linyphiidae.

Smooth caterpillars like those of winter moth are not greatly favoured, although they may be accepted.

Bristowe considers it unusual for spiders to kill and eat mites, for in his experiments with the mites *Allothrombium fuliginosum* Herm. (a beneficial species in orchards, Massee, 1932), *Halotydeus* sp., *Anystis baccarum* L., *Erythraeus regalis* Koch, *Pergamasus crassipes* L. and *Oribata globula* Michael, on only one occasion was a mite eaten, viz., *P. crassipes* by *Theridion bimaculatum* (L.). The spiders tested were of the families Argiopidae, Theridiidae, Linyphiidae, Salticidae, Tetragnathidae, Dysderidae, Clubionidae, Thomisidae, Lycosidae, and several others not yet recorded from fruit trees.

During the present study an investigation of the range of insects and mites, commonly found in orchards, which are acceptable as food to common orchard-inhabiting spiders was conducted. The results of this are summarized in Table IV. Unless a spider fed readily and continuously on a particular prey species, it was not considered to accept that species for food.

TABLE IV.

Variety of insects acceptable as food to species of spiders commonly found in orchards.

Spider species	Food species											
	Mites					Hemiptera-Homoptera					Others	
	M. ulmi	*B. praetiosa*	*Typhlodromus tiliae*	*Sphaerozetes lapidarius*	*Humerobates rostrolamellatus*	*Psylla mali*	*Aphis pomi*	*Blepharidopterus angulatus*	*Anthocoris nemorum*	*Psallus ambiguus*	*Operophthora brumata* larvae	Thrips sp.
Theridion pallens ..	†*	†*	†*	‡	‡	†*	*	‡	‡	*		‡
Immature Erigoniids ..	†	†	†			†	†	†	‡	†	‡	
Erigonidium graminicola	†*	†*	†*	†*	*		†*	*	‡	*		*
Entelecara acuminata ..	†*	†*	†*	†*	*		†*	*	‡	*		*
Araneus cucurbitinus	†	†	‡	‡	‡		‡	†*	‡	†*		†*
Misumena vatia ..	†	†					†*	†*	*	†*	*	†*
Lycosa sp. ..		‡							‡			
Cyclosa conica ..	†	†				‡	‡	†*	‡	†*	‡	†*

* Denotes eaten by adult spider.
† Denotes eaten by immature spider.
‡ Denotes spider refused to feed.

Capsids and Anthocorids were eaten only when immature by smaller spiders (e.g., Linyphiids and Theridiids) but the larger spiders fed readily on the adults.

It is surprising that predacious mites of the genus *Typhlodromus* should be subject to attack from spiders for, in addition to being minute, they are very quick and difficult to capture. Also, it was not expected that spiders would feed on *Humerobates rostrolamellatus* or *Sphaerozetes lapidarius*, which are heavily-armoured Oribatid mites. Both of these are considered beneficial in that they feed on bark-infesting algae on fruit trees (Massee, 1932).

Most of the spiders listed fed readily on members of the Hemiptera-Homoptera, as well as on mites. This is at variance with the observations of Bristowe. Perhaps orchard-inhabiting spiders have become adapted to feeding on these animals, which are the most plentiful that occur in orchards.

The larger species of spiders tested fed readily on insect predators of orchard pests. This was not reciprocal, however, for predacious insects were not recorded as feeding on the spiders during this study.

Spiders, like many predacious animals, are initially attracted by the movements of their prey. For this reason those tested did not feed on the eggs of *M. ulmi* or *B. praetiosa* and only occasionally on the quiescent stages. They fed but rarely on larval or protonymphal stages, which are probably too small to attract their attention.

The feeding capacities and preferences of only a few Linyphiid and Theridiid spiders recorded in orchards were tested but undoubtedly similar data could be obtained for other species.

FIELD OBSERVATIONS.

The most common orchard-inhabiting spiders belong to the families Theridiidae and Linyphiidae. In general the former are small spiders (2-3 mm. when adult, with the exception of *T. ovatum*) with the abdomen globular. Usually the basic colour of the abdomen is white or cream, and there may be dark-brown or black markings. The legs are fairly long relative to the body length and may be variously annulated.

Theridiids are found almost invariably on the leaves and petioles, where on occasion they spin webs of the type shown in Fig. 1, c. Insects such as adult *Psylla mali* and immature capsids are sometimes found in these. However, Theridiidae

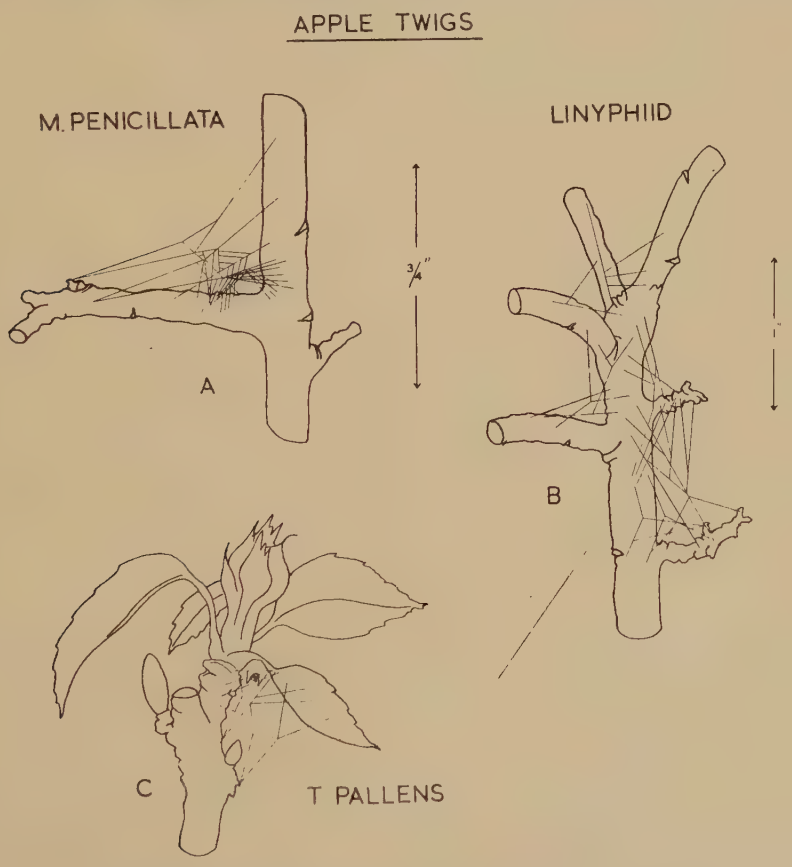

FIG. 1.
Types of Spiders' Webs : A and B, Linyphiid ; C, Theridiid.

spend considerable time searching over the foliage for their prey. This statement differs from others given in the literature, but is based on frequent field observations. Theridiids are not efficient at searching, as is indicated by the differences between the numbers of mites consumed at high and low prey densities (Table III). Even at low densities many mites were not eaten, although the spiders had not fed to capacity; they seemed to limit their activities to the petioles and edges of the leaf laminae with the result that they had little contact with the dense congregations of mites along the mid-rib.

Theridiids paralyse their mite prey, and then usually drop on a short strand of silk and consume the mite while hanging beneath the leaf. It may require from 3-30 minutes for the contents of the mite to be completely ingested. Frequently the spider will be attracted by and attack other mites while already feeding on a mite. Once paralysed these fresh mites are left until the first has been finished. When the spider has completely ingested the contents of a mite, nothing remains but a perfect, empty, colourless skin. Theridiids feed in cycles, apparently consuming 5-10 mites within a short time, and perhaps not feeding again for nearly 24 hours. Because they prefer the leaves to the bark of fruit trees, these spiders probably are of greater importance in reducing populations of *M. ulmi*, which is exclusively a leaf-inhabiting species, than of *B. praetiosa*, which spends much of its life on twigs and small branches.

Linyphiids inhabiting orchards are also small (2-5 mm. in length) and usually have a somewhat less globular abdomen. This is frequently shining black and without markings. The legs are also long and are usually yellow to reddish-brown and without annulations.

Linyphiids, although commonly found on leaves, seem to prefer the wood of apple trees, particularly the smaller branches and twigs. Here they spin their characteristic webs (Fig. 1, a and b) and to some extent roam in search of prey. For this reason they are thought to be of more importance in the control of *B. praetiosa* than of *M. ulmi*. However, they have been observed feeding on females of the latter species when they move on to the bark in autumn to lay winter eggs. Linyphiids require from 2-10 minutes to ingest the contents of an adult mite and, unlike the Theridiids, roll the body of their prey between their chelicerae when extracting its contents; consequently, all that remains after feeding is a tightly compressed, dry, brownish ball which bears no resemblance to the original form of the mite. When searching leaves or bark for prey, these spiders prefer the more shaded sites, thus differing from the Theridiids, which prefer the edges of the leaves.

CONCLUSIONS.

Certain spiders, particularly small species and immature forms, feed readily on phytophagous orchard mites. The larger species usually confine their feeding to other orchard insects, notably to winter moth larvae, apple suckers and aphids, and to predacious insects.

Though no claims are made concerning the importance of predacious spiders in controlling orchard pests, they are shown to feed readily on a range of species. Because certain species of spiders are present from early summer until late in the autumn, they may be of equal, or even greater importance than other predators whose total consumption of mites may be little, if any, greater although more spectacular, because it takes place over a shorter period of time.

SUMMARY.

1. A list of the species of spiders found in some sprayed and unsprayed orchards in Kent and Essex from 1952-55 is presented, together with an indication of their relative abundance.

2. It is shown that certain common species of spiders feed readily on phytophagous mites, the numbers consumed tending to increase with the density of prey.

3. The results are given of observations on the range of common orchard-inhabiting insects and mites acceptable as food to various species of spiders, and notes are included on the habits of spiders of the families Theridiidae and Linyphiidae.

ACKNOWLEDGMENTS.

The author wishes to thank Dr. A. M. Massee, Head of the Entomology Section, East Malling Research Station, Kent, under whose direction this work was conducted, for his interest and advice concerning certain aspects of the work. Thanks are also due to Mr. A. Turnbull, Agricultural Research Officer, Canada Department of Agriculture, for his advice and criticisms of this paper and to Mr. E. Browning, British Museum (Natural History) for initial help with identifications. The work was done at the East Malling Research Station, Kent, and for the year 1953-54 a Special Scholarship for Overseas Study was granted to the author by the National Research Council of Canada ; this is gratefully acknowledged.

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(*Received* 22/4/55.)

OBSERVATIONS ON THE NATURE AND DEVELOPMENT OF STRUCTURAL DEFECTS IN THE UNIONS BETWEEN PEAR AND QUINCE

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The immediate cause of the mechanically weak unions that occur in some incompatible trees is by now well known. They are due to the abnormal arrangement of the xylem tissue, particularly the fibres, which, instead of interlocking across the union, either curve in a horizontal direction or are separated by a layer of parenchymatous tissue. This has been well described by Proebsting (1928), Bradford and Sitton (1929), Eames and Cox (1945), Herrero (1951) and others. All are agreed that the discontinuity of the vascular tissues is due to some interruption, temporary or permanent, of normal cambial activity at the point of union, but there is as yet little information regarding the basic causes of this interruption. Most anatomical investigations of the union have been concerned primarily with the structure of the woody cylinder, although, as long ago as 1929, Bradford and Sitton wrote, " the break-down in the bark seems more consistent, more complete and perhaps more important than that in the wood ". The first attempt to explain the break in cambial continuity was made by Herrero (1951) who concluded from his anatomical investigations that there existed in incompatible combinations a latent antagonism between adjoining cells of stock and scion, and that spontaneous breaks occurred in the cambial layer at the point of union, possibly in connection with changes undergone at the union by substances elaborated in the leaves. Thiel (1954) agrees that the underlying causes of pear/quince incompatibility are probably biochemical in nature. It is believed that further evidence for this view is provided by observations which have been made at East Malling on the histology of the bark tissue in some pear/quince unions and which will be described in this paper.

Material and method.

The material consisted of two sets of pear trees of the variety Williams' Bon Chrétien (W) on quince rootstocks.

Trees in the first set were fifteen years old, and had been double grafted on Quince A (QA) or Quince C (QC) with a 2-foot intermediate stem-piece of either Beurré Hardy (Hd), Fertility (F), Hessle (Hs), Beurré d'Amanlis (A) or Williams' (W). A macroscopic examination was made of the longitudinally sawn unions of two trees of each of the following combinations :

W/Hd/QA (four trees), W/F/QA, W/Hs/QA, W/A/QA, W/W/QA, and W/QA (single budded) ; and a similar set on QC rootstocks.

A microscopic examination was made of the lower union of six of these trees, one each of the following combinations :

W/Hd/QA, W/F/QA, W/W/QA ; and a similar set on QC rootstocks.

The other material consisted of three-year-old single- and double-shield budded trees (Garner, 1953) of W/QA and W/Hd/QA respectively. A macroscopic

examination was made of the union in eight trees of each combination, and six lower unions of W/Hd/QA and two of W/QA were examined microscopically.

In the macroscopic examination, unions were sawn longitudinally and the bark peeled off one half of the trunk to expose the woody cylinder. The quality of the unions was recorded in the usual way (Herrero, 1951, pp. 213-14) and, as it was somewhat variable at different points along the union, the two halves of each section were recorded separately. Particular attention was paid to the bark, which was recorded in four categories, as follows :

1. Cortex and phloem discontinuous, with a black or dark brown separation layer at the union.
2. Cortex discontinuous, line of union in phloem marked by a light brown separation layer of slightly water-logged appearance.
3. Cortex discontinuous, no separation layer visible in phloem.
4. Cortex and phloem continuous, no separation layer visible.

It is possible that the region described as the cortex in these observations may have included some parts of the older phloem.

Material used for the microscopic examination was fixed in formalin-acetic-alcohol in order to preserve the details of the bark-structure which was the object of special study. Sections were cut on a sledge microtome, stained in the usual way in safranine and light green, and mounted in Canada balsam. Radial longitudinal, tangential longitudinal and transverse sections were cut of each union. The transverse sections were in series from about 3 mm. above to 3 mm. below the union, so that observations could be made on the distribution of damaged tissue through the union.

Results.

Macroscopic structure of the unions.

In the fifteen-year-old trees all the top unions between the scion (Williams') and the intermediate (another pear variety) were very good, and it was impossible to follow the actual line of union, either in the wood or the bark. In all the lower unions (between a pear intermediate and a quince rootstock) the line of union could be clearly seen, and in the bark the separation layer between them was often very pronounced. On the whole, unions on Quince A were better than those on Quince C. A summary of the observations made on the structure of the lower unions is given in Table I. Trees are grouped according to the variety of the intermediate, irrespective of the rootstock, and the results are expressed as percentages. Since two separate observations were made on each union, there are two records for each tree.

Points of special interest arising from these figures are :

1. The structure of the W/Q unions differed from the Hd/Q unions in two respects:

(*a*) The wood was " mostly discontinuous " in 62·5 per cent. of the incompatible W/Q and in 6·2 per cent. of the compatible Hd/Q unions. The other varieties used as intermediates resembled Hardy.

(*b*) The separation layer in the bark extended across the phloem and up to the cambium in 50 per cent. of the W/Q and in 12·5 per cent. of the Hd/Q unions. The other varieties resembled Hardy.

2. There was a more or less uninterrupted separation layer in the cortex of all the unions examined. In this respect Williams' (18·8 per cent. continuous cortex)

TABLE I.

Percentage of pear/quince unions showing a particular type of structural defect.

Intermediate :	Williams'	Hardy	All varieties other than Williams'
No. of trees examined :	(8)	(8)	(20)
Structure of Wood :			
Mostly disc.	62·5	6·2	7·5
Disc. in patches	37·5	43·7	67·5
Continuous	0·0	50·0	25·0
Structure of Bark :			
Cortex and phloem disc.	50·0	12·5	15·0
Cortex disc., phloem slightly disc.	6·2	18·8	25·0
Cortex disc., phloem continuous ..	25·0	68·8	50·0
Cortex and phloem continuous ..	18·8	0·0	10·0

disc. = discontinuous.

did not differ much from the other varieties (10 per cent. continuous cortex). That such a separation layer is a common feature of many pear/quince unions, irrespective of their horticultural compatibility, has been observed on many occasions. It is interesting that such a layer across the cortex can also be clearly seen in Thiel's (1954) illustration of a union of the variety Gellert (commonly used as an intermediate in Germany) on Quince A rootstock.

3. The figures show that some anatomical symptoms of incompatibility existed in the bark structure of all, and in the wood structure of most pear/quince unions, irrespective of whether the pear was the incompatible variety Williams' or a variety regarded as horticulturally compatible, i.e. Hardy, Hessle, Fertility or d'Amanlis. The observations thus support the view that incompatibility is very much a matter of degree, so that the horticultural separation into compatible and incompatible varieties is to some extent a matter of practical convenience and of interpretation. Such a view is also supported by the practical experience that trees of incompatible combinations may remain quite satisfactory throughout their life provided that they do not break off. The anatomical structure of the union appears to provide a sensitive indicator of incompatibility, even in its milder forms.

The figures for the union structure of the three-year-old single- and double-shield budded trees are given in Table II. The differences in the union structure of W/QA and Hd/QA substantially confirm those observed in the older trees.

Microscopic structure of the unions.

Eight unions of Hardy/Quince (of two different ages), two of Fertility/Quince and four of Williams'/Quince were examined microscopically. Most of the observations to be described were made on Hd/Q unions because the anatomical abnormalities occurring in these, though similar in kind, were considerably less in degree. They could therefore be more easily seen than in the worse unions of incompatible combinations which have been the main object of previous studies.

Abnormalities found in the microscopic structure of tissues at the union were of three kinds : (1) the occurrence of necrotic cells, isolated or in groups ; (2) the

TABLE II.

Percentage of unions from single- and double-shield budded trees showing a particular type of structural defect.

Union : No. of trees examined :	Williams'/QA (8)	Hardy/QA (8)
Structure of Wood :		
Mostly disc.	100	25
Continuous	0	75
Structure of Bark :		
Cortex and phloem disc.	100	50
Cortex disc., phloem slightly disc.	0	25
Cortex disc., phloem continuous	0	25
Cortex and phloem continuous	0	0

disc. = discontinuous.

excessive proliferation of rays ; and (3) the involution of the cambial zone with occasional breaks in the continuity of the xylem tissues.

(1) *Occurrence of necrotic cells.* The six diagrams in Fig. 1 show the distribution of necrotic cells in a three-year-old union of Hardy/Quince A, which was typical in this respect of all the other unions examined. The diagrams, which were made by tracing the projected images of a series of transverse sections cut at vertical intervals of $\frac{1}{2}$ mm., include the bark only. From each section the part showing the greatest damage was selected for drawing.

The most important microscopical observation was that, at all levels of the union, damage was least in the one-year-old phloem, and only rarely affected the most recently formed phloem close to the cambium (Fig. 1). Invariably the largest amount of necrotic tissue occurred at or close to the point of union, diminishing rapidly on either side of it, and disappearing almost completely at a distance of approximately three millimetres. This is shown by the smaller number of necrotic areas in diagrams 1 (Hardy) and 6 (Quince A) and their greater extent in diagrams 2 to 5 which represent sections closely adjoining the union in a vertical or lateral direction. (While, to judge from the phloem fibre rings, the union between Hardy and Quince A occurred somewhere between diagrams 5 and 6, it must be remembered that the union runs more or less diagonally across the trunk, whereas the sections were cut transversely, and therefore diagrams 2, 3 and 4 may also have been closely adjacent to it in a lateral direction.)

The concentration of necrotic areas around the union was also very evident in longitudinal sections (Fig. 2). In the unions illustrated in Figs. 1 and 2 there was more necrosis in the pear than in the quince, but this, while fairly common, was not always so. Necrosis seemed to originate in individual sieve tubes in older parts of the one-year-old phloem (Fig. 3), the first dead cells frequently occurring at the edges of rays (Figs. 1, 2 and 3). The shape of the larger necrotic areas strongly suggested that the agency causing death had spread along the rays (Fig. 1), and not infrequently entire rays were necrotic for part of their length (Fig. 4). Large necrotic areas which occurred extensively in the outer phloem, especially near its junction with the cortex (Fig. 1), were usually surrounded by a phelloderm.

STRAWBERRIES. Bulletin 95, Ministry of Agriculture, Fisheries and Food. 5th Edition. (London : H.M. Stationery Office. 1955. Pp. 44, illus. Price 2s. 6d.)

This valuable handbook for both the established strawberry grower and the newcomer to the industry has been considerably revised and brought up to date.

The chapter on varieties now includes descriptions of three Cambridge varieties, Favourite, Rearguard and Vigour, chosen no doubt for the particular qualities which have gained them a limited place in the strawberry field, rather than for their flavour.

In the list of maincrop varieties it is sad to see that Auchincruive Climax has never reached the distinction of capital letters, although between the 1949 and 1955 editions of this publication it must have been the most widely planted and the most financially rewarding strawberry in the country. The genetic breakdown of this excellent variety is dismissed in one short sentence. As this trouble may well recur in any new variety, a short account of its history and characteristics would have been a useful addition to the bulletin.

The newly released Scottish variety Talisman, which was bred by Mr. Reid at Auchincruive and had Climax as one of its parents, is also described.

Modifications in terminology help to clarify the complicated subject of tolerance and sensitivity of strawberry varieties to virus diseases but further improvement could be made here. Descriptions of runner-raising methods have been brought into line with current practice, and there are appendices on the Certification Scheme and the Nuclear Stock Scheme. Progress has already outstripped publication, however, with the release, as a result of heat therapy, of the first virus-free Special Stocks of the previously totally infected varieties Huxley and Perle de Prague.

The sections on planting, manuring and general culture are sound and comprehensive, if rather wordy, and cover the best practices of the main strawberry growing areas. The matted-bed planting system described is that used in America, whereas the illustration shows a similar system with far fewer original plants, which has been tried in this country and found liable to drought injury in low rainfall districts.

Growers who are turning to cloches as a means of producing both early and late strawberries will welcome the entirely re-written section on out-of-season production.

Pests and diseases are again fully dealt with, though a peculiarity of arrangement allows them all to appear under the general heading of Virus Degeneration.

Finally, the startling new cover design is a useful reminder that the new edition should be acquired to supplement or replace the old.

D.J.W.

EMBRYOGENESIS IN PLANTS. By C. W. Wardlaw. (London : Methuen & Co., Ltd. ; New York : John Wiley & Sons, Inc. 1955. Pp. 381, illus. Price 42s.)

In plants, the embryo is defined as the rudimentary plant contained in the seed. Since this definition would have greatly limited the scope of the book, Professor Wardlaw has interpreted " embryo " in such a way as to include development in the Algae, Bryophyta, Psilotales, Equisetales, Lycopodineae, and the ferns. Indeed, the first ten chapters, comprising 170 pages, are devoted to these more primitive groups, while the true flowering plants are dealt with in some 70 pages.

There is no doubt that Professor Wardlaw has done a great service to a specialized branch of science in gathering together all the mass of data contained in this book. It is to be hoped that this will stimulate further work on plant embryogeny so as to advance our knowledge of the subject at least to the level of the comparable field in zoology. Apart from the more straightforward knowledge of planes of cell division and of polarity in the earliest stages of embryo development, the science of embryogeny is still largely in its infancy and ideas as to causation of the various phenomena appear distinctly nebulous. In the author's own words : " What factors are involved in the assumption of form, and in the successive changes in form, during the ontogenetic development, and likewise in the differentiation of the increasingly complex tissue systems ? These are questions which we must attempt to answer . . . Even if we cannot explain any but a few of the phenomena, it is important for the advancement of botanical science that the relevant problems should be clearly before us."

In the section dealing with flowering plants there is a valuable discussion of comparative embryology in relation to taxonomy, but here again the limited extent of our present knowledge is all too evident. This is in no sense a criticism of the present work ; indeed the author constantly stresses the vast field still to be explored, and workers in this field should find his discussions of the various problems both stimulating and valuable.

The penultimate chapter includes sections on induced parthenogenesis and on embryo culture which should prove of particular interest to plant breeders.

The publishers are to be congratulated on the standard of printing and the clarity of diagrams ; the reviewer found only one typographical error in the whole book.

R.L.K.

PUBLICATIONS RECEIVED.

GRAPES. By H. Parsons. (London : W. H. & L. Collingridge Ltd. 1955. Pp. 64, illus. Price 10s. 6d.)

ROCK GARDENING. By G. K. Mooney. (London : W. H. & L. Collingridge Ltd. 1955. Pp. 92, illus. Price 3s. 6d.)

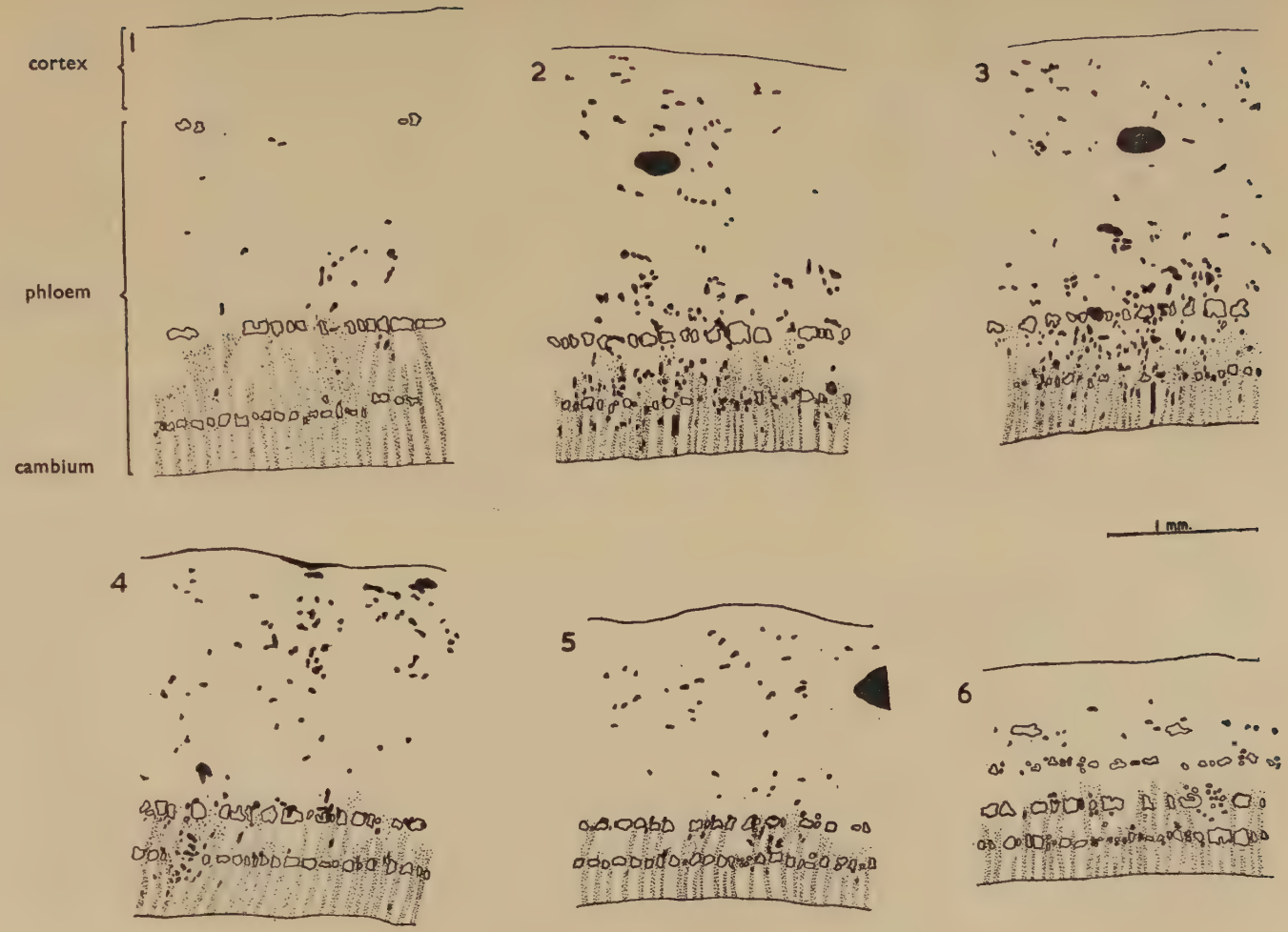

FIG. 1.

Diagrams showing the distribution of necrotic cells in a series of transverse sections cut at vertical intervals of $\frac{1}{2}$ mm. in the region of the lower union of a three-year-old shield-budded tree of Williams'/Hardy/Quince A. The solid black areas represent the necrotic tissue, stippled areas the rays, and ringed areas the phloem fibre blocks. (Tracings of projected images).

(2) *Proliferation of the phloem rays.* Frequently associated with the occurrence of necrotic areas was an excessive proliferation of the rays. These are represented in Fig. 1 by the lightly dotted areas, and in diagrams 1, 3 and 4 actual fusion of rays with consequent obliteration of the intervening sieve tube areas can be seen. As with necrosis, such abnormal proliferation of the phloem rays occurred only in a region closely adjoining the union, and rays in the one-year-old phloem, though not entirely normal, were considerably less affected than those in the two-year and older phloem. In most specimens proliferation of the rays occurred only after the first ring of phloem fibres had been laid down. This is shown in Fig. 5, and also by the predominantly regular arrangement and spacing of the fibre blocks illustrated in Fig. 1. When ray proliferation did occur earlier, as in diagram 4, no fibres were formed at the end of the current year's phloem. The conclusion that abnormal proliferation in the rays did not occur at their inception from the cambial ray initials but developed later, is supported by the fact that the corresponding xylem rays, formed at the same time from the same cambium, were practically always normal. The proliferating phloem rays were abnormal also in their staining reaction, and assumed a deep purple colour with safranine and light green.

(3) *Breaks in the continuity of the xylem tissues.* Since most of the unions examined were relatively good, only a few of the sections showed abnormalities in the xylem structure. These comprised the usual involutions of the cambial zone and breaks in the continuity of the vascular tissue which have been described by Bradford and Sitton (1929), Herrero (1951) and others. It was noted that the parenchymatous layer separating the vascular tissue of stock and scion frequently originated from an enlarged ray, and that often a line of dead cells occurred in its centre (Fig. 6). The observation was confirmed that breaks are more common in the autumn wood, and that cambial continuity may be re-established in the spring. In some instances a break, which became apparent for the first time in the autumn wood, was preceded at the beginning of the annual ring by a slight proliferation and by the presence of a few dead cells within the ray that eventually initiated the parenchymatous layer (Figs. 6 and 7). Such rays showed a normal structure in the intervening period. It was also observed that, whenever a break in the xylem tissue occurred, the corresponding phloem tissue was invariably much worse affected, with large necrotic areas and extensive ray proliferation extending right up to the cambial zone (Fig. 6).

An attempt was made to measure the radial spread of the separation layer in an annual wood ring and its corresponding phloem ring. In ten sections the separation layer occupied from 13 to 88 per cent. of the radial width of the last wood ring (mean of ten sections = 41·4 per cent.), whereas it invariably occupied the entire radial width of the corresponding phloem ring.

DISCUSSION.

In discussing pear/quince incompatibility, it is important to consider the following points. All pear/quince unions, whether horticulturally compatible or not, showed some symptoms of incompatibility in their bark structure. In no union did a break occur in the continuity of the woody tissues without a corresponding separation layer in the bark. This observation is contrary to the findings of Rhandawa and Upshall (1949) who recorded pear/quince unions with continuous bark and discon-

PLATE 1

Fig. 2.

Longitudinal tangential section through the bark of a union of Fertility (above) on Quince A (below) from a fifteen-year-old tree of Williams'/Fertility/QA. Note the concentration of necrotic areas near the union (indicated by arrows), and their spread along the edge of the rays. A proliferating ray with a central necrotic area is labelled (PR).

Fig. 3.

Transverse section of the current year's phloem near the union of Hardy/Quince A from a fifteen-year-old tree of Williams'/Hardy/QA. The latest formed ring of phloem fibres can be seen at the top of the photograph, and the phloem shown at the bottom was close to the cambium. Some dead cells are indicated by arrows.

face p. 52

FIG. 4.
Transverse section of bark near union of Hardy/Quince A from a fifteen-year-old tree of Williams'/H/QA, showing spread of necrosis along rays. Phloem shown at A was close to cambium.

FIG. 6.
Transverse section of break in continuity of vascular tissue near union of Hardy/Quince A from a three-year-old double-shield budded tree of Williams'/H/QA. Note necrotic centre of parenchymatous layer, extending across part of annual wood ring and whole of corresponding phloem ring.

FIG. 5.
Detail of proliferating ray shown at A in Fig. 4. Note sudden widening of rays just above phloem fibres (F).

FIG. 7.
Transverse section showing, at beginning of annual ring, the ray from which parenchyma layer shown in Fig. 6 originated later in the season.

tinuous wood. Since, however, the observation is followed by the remark, " All of these combinations showed a more or less prominent brown layer at the union ", the difference seems to lie more in the definition of the word " continuous " than in the appearance of the unions. Even where the separation layer was not microscopically visible, tissue abnormalities occurred at the union in the form of excessive proliferation of phloem rays, and of dead cells, singly or in groups. Their distribution suggested strongly that they originated, not at the cambium, but in older parts of the one-year-old phloem, and that necrosis generally started in individual sieve tubes and spread radially in the rays.

These observations have a bearing on our conception of the differences between compatible and incompatible pear varieties, and of the mechanism responsible for the breaks in cambial continuity of pear/quince unions. Whereas Herrero (1951) thought that such breaks were initiated by the spontaneous death of adjoining cambial cells of stock and scion, it now seems more probable that necrosis begins in the phloem at some distance from the cambium, that it spreads inwards towards the cambium along the rays and is able to reach the cambium and initiate new breaks in the woody tissue at times when the rate of cambial activity is slowed down as a result of seasonal or other causes. This view is supported by the direct evidence of the distribution of necrotic cells at the union—their absence from the recently formed phloem and preponderance in the two-year and older phloem—and by the evidence of their spread along the rays. Indirect evidence is provided by the unequal distribution of abnormal tissue in wood and bark ; if both originated from damage in the cambium, xylem and phloem might be expected to show the same degree of abnormality. Further support is given by the observation, made by Herrero and others, that breaks in the woody cylinder frequently start from a ray.

The above explanation of the origin of breaks in cambial continuity would also explain why they occur more frequently in the autumn and why, at any particular time, breaks occur sporadically at different points in a union rather than uniformly along it. If initiation of a break in the woody cylinder depended on the relative rate of accumulation and spread of a substance causing necrosis and the rate at which affected areas are pushed away from the cambium by the formation of new phloem tissues, then it is clear that the cambial zone would be reached more frequently in the late summer and autumn when formation of new tissues only proceeds slowly. Moreover, small local differences in growth rate, or in the accumulation or spread of lethal substances, could account for the irregular initiation of new breaks at different points along the union. The observations on the bark continuity of Williams'/Quince and Hardy/Quince suggest that there may be varietal differences in the rate at which lethal substances accumulate and spread towards the cambium, thereby affecting the degree of compatibility, and that this is determined by quantitative rather than by qualitative characters. While it would be of considerable interest to expand these anatomical observations and, if possible, to extend them to the unions of other species (such as plums), it seems improbable that they can by themselves lead to an understanding of the basic causes underlying incompatibility. They might, however, do so in conjunction with a seasonal survey of the biochemical constituents of the bark tissue at the union.

SUMMARY.

The following observations were made on the union structure of some fifteen-year-old and some three-year-old trees of Williams' Bon Chrétien on quince root-

stocks. The older trees were double grafted with a 2-foot intermediate of Beurré Hardy, Hessle, Fertility, Beurré d'Amanlis or Williams' and the younger trees were single-budded, or double-shield budded with an intermediate of Beurré Hardy.

(1) All pear/quince unions, irrespective of the horticultural compatibility of the intermediate used, showed a well marked dark brown separation layer between the outer bark of pear and quince.

(2) All pear/quince unions showed some microscopic evidence of uncongeniality in the form of abnormal proliferation of the phloem rays, and of necrotic cells occurring singly or in groups in the bark at or very close to the union. The largest amount of necrotic tissue occurred in the two-year and older phloem, and the damage appeared to originate in older parts of the one-year-old phloem and to spread in the rays.

(3) The extent of the microscopic abnormalities, and of the spread of the separation layer into the inner phloem and up to the cambium, appeared to be related to the degree of horticultural compatibility of the pear variety used as intermediate.

The bearing of these observations on the problem of compatibility between pear and quince is discussed, and the hypothesis is advanced that breaks in the continuity of the woody tissues arise when lethal substances, which accumulate in the older phloem near the union, are able to reach the cambium.

ACKNOWLEDGMENTS.

We wish to thank Mr. R. J. Garner who kindly provided the material for this study.

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(*Received* 3/6/55.)

EFFECTS OF CONTROLLED ROOT TEMPERATURES ON THE GROWTH OF EAST MALLING ROOTSTOCKS IN WATER CULTURE

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DWARF and semi-dwarf apple trees have not been so extensively planted in North America as in Europe. Recently, however, orchardists in America have become increasingly interested in the smaller than standard tree as one means of reducing the sharply rising costs of management.

Rootstocks of most apple trees on the North American continent are of seedling origin and as such are often variable in vigour, hardiness and disease resistance. On the other hand, clonal rootstocks produce a known degree of vigour and precocity in the scion variety (Hatton, 1927, 1935 ; Pearl, 1932 ; Maurer, 1939 ; Tukey, 1944), and Hatton (1926) has suggested their superiority to seedling rootstocks.

The performance of the most important clonal apple rootstock series, known as the East Malling rootstocks (Hatton, 1917, 1927, 1935) has been perplexing, and has not been critically evaluated under the various culture conditions of North America. Their failure in the northerly regions, due to lack of hardiness, is well understood, but poor success in the southern apple growing regions has been puzzling. Attention is naturally focused on features of climate, and soil temperature would be one of such factors. Harris (1926), Nightingale and Blake (1934), Nightingale (1935), Collison (1935), Rogers (1939), Batjer *et al.* (1939) and Proebsting (1943) have reported on the effects of soil temperature on shoot and root growth of apple trees.

Further, from the reports of Beakbane (1953) and Beakbane and Thompson (1939, 1945, 1947), anatomical characteristics of the apple root would appear to be criteria for the selection of dwarfing rootstocks. This would imply that anatomical features of root systems are constant, but Nightingale (1935) observed that soil temperature markedly affected the anatomy of apple roots. Similar results were obtained with roses (Shanks and Laurie, 1949), colonial bentgrass (Stuckey, 1942) and Kentucky bluegrass (Darrow, 1939).

This paper presents the results of experiments designed to evaluate the effect of root temperature on the growth, development and anatomical characters of certain East Malling rootstocks.

EXPERIMENTAL METHODS.

Equipment.

The experiments were conducted in controlled temperature tanks (Fig. 1A), as constructed and described by Roberts (1953). Essentially, the unit tanks were reinforced round-end livestock troughs enclosed in well-insulated plywood boxes. A standard centrifugal pump of 6-gallons-per-minute capacity circulated the water, the temperature of which was controlled by heating cables and refrigeration units.

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Roberts' containers were crocks of sand, but for root observation these were replaced by 1-gallon, wide-mouthed glass jars containing nutrient solution. A removable metal collar excluded the light around the neck and shoulder (Fig. 1A) and facilitated removal of the jar for periodic inspection.

Each jar was aerated and the volume of supplied air under pressure was controlled by individual screw clamps. At first the jars were fitted with perforated plastic aerators (Fig. 1B) but later the plastic materials in the entire system were replaced by glass capillary tubing because at the higher temperatures algal growth on the plastic plugged the perforations.

The lids of the jars were punched with five one-inch holes. The young trees were inserted through three of these and held in place by a rubber collar and non-absorbent cotton wool (Fig. 1B). Air was supplied through a piece of 7 mm. glass tubing held in place by a rubber stopper inserted in the fourth hole, while the fifth hole was stoppered and used for the addition of nutrients and water without disturbing either the plants or the air supply.

Plant material.

The East Malling rootstocks investigated were M.IX, M.VII, M.I and M.II, and M.XVI representing respectively very dwarf, semi-dwarf, vigorous, and very vigorous rootstocks. The clones had been obtained from the East Malling Research Station and multiplied in a stoolbed at Michigan State University. Sufficient rooted shoots were removed to a nursery cellar in the fall to permit the later selection of 24 of each clonal rootstock for uniformity in girth, amount of root and freedom from disease. They were top-pruned to 8 inches and returned to storage.

For comparison with the East Malling series, a rootstock of Seedling origin was pruned and inserted in jars of nutrient solution immediately after arrival from a commercial nursery. On the same date, 11th February, 1954, the East Malling rootstocks were also inserted in the jars of nutrient solution. All stems were marked with a streak of paint 1 inch above the jar lid.

Temperatures.

Tank temperatures, held constant throughout the experiment, were 44°, 55°, 66° and 77° F.

Nutrient solutions.

The plants were first placed in a 0·5 Hoagland nutrient solution, but after three weeks, when growth was well started, the concentration was increased to a 1·0 Hoagland nutrient solution (Hoagland and Arnon, 1950). When the plants were small, the solutions were renewed at three-week intervals but, as growth increased, renewals were more frequent, the last three being weekly. Between changes of nutrient solution, the level in the jars was adjusted daily with distilled water to keep the total nutrient salts uniform in each temperature treatment. All the experiments were maintained for a period of 75 days.

Growth measurements.

The following records were made :

First emergence of new roots ; first bud break ; initial and final diameters at paint streak ; final diameter of new growth at 1 inch from junction with old stem ;

linear elongation of new shoots ; fresh and dry weight of each shoot, stem and leaves included ; fresh weight of new roots on each plant, and oven-dried weight of new roots per treatment.

The jars had to be removed from the tanks to record new root emergence, but thereafter the plants were disturbed as little as possible. At first bud break, the remaining buds were removed, as were the later-formed axillary buds. This procedure held the new shoots to a single stem.

Sampling.

Samples from various parts of the roots were fixed in a FAA solution (5 ml. of 40 per cent. formaldehyde, 5 ml. of glacial acetic acid, and 90 ml. of 70 per cent. ethyl alcohol) and aspirated immediately. The material was dehydrated in a tertiary butyl alcohol series (Johansen, 1940) and embedded in histowax. Transverse sections, 8 microns in thickness, were cut at 5, 7½ and 10 cm. from the root apex and stained in safranine and aniline blue (Johansen, 1940).

Experimental results.

The temperature of the medium influenced the growth of the apple rootstocks. In general, both root and shoot growth were affected similarly (Figs. 2 and 3).

No plants of M.IX or M.II survived the 66- and 77-degree F. treatments. M.II did not grow well at 55° F. and half the plants in this treatment died, while the losses in other series included one plant of M.VII at 77° F. and one of M.I at 66° F. and one at 77° F. On all dying plants the new roots first showed a translucent browning near the base and this discoloration developed towards the root apex. Within ten days of first discoloration the roots of the affected plants were reduced to a slimy mass and the shoot was withered and chlorotic.

Although all of the Seedling rootstocks survived, regardless of temperature treatment, they varied in production of new roots. Of the six plants in each treatment, only three formed roots at 77°, four at 66°, four at 55°, and none at 44° F. Individual shoot growth was correspondingly affected.

Root growth.

In general, new roots were initiated significantly sooner at the higher temperatures. *M.I :* Root growth was greatest at 55° F., and this was significantly greater than at the 44° and 77° F. treatments. *M.IX:* Growth at 55° F. was significantly greater than at 44° F. *M.VII* and *M.XVI :* Root growth was greatest at 77° F., and the growth at 77°, 66° and 55° F. was significantly greater than at 44° F. *M.II* and *Seedlings:* Death of a large number of M.II plants at the higher temperatures and failure of some plants of the Seedling rootstock to form roots at all temperatures precluded statistical analyses of results of these populations. However, at 55° F., M.II produced more root growth than at 44° F. The Seedlings produced no new roots at 44° F. but, in those plants that formed new roots at 55° to 77° F., root growth increased with temperature increase.

When the root material was harvested, all roots in the 44° F. treatments were white but, at temperatures above the different growth optima for the various rootstocks, many of the roots were browned and their cortex ruptured, this condition increasing from rupture to complete sloughing (Fig. 4). M.I, the most adversely affected, had not only severely browned roots but also considerable cortical debris

in the bottom of the jar at 77° F., a condition less marked in the 66° F. treatment. At 55° F. the majority were white, but at 66° and 77° F. half to more than half were discoloured. Compared with the other rootstocks grown at 44° F., new roots of M.I had made good growth.

M.II and M.IX produced much lenticel callus, particularly in the higher temperature treatments. At 55° F. this callus was conspicuously discoloured and roots were also somewhat browned. The callus was very soft and spongy and might well have been the point of entry for a Phycomycete organism that ultimately destroyed the root systems.

White roots predominated in M.VII, M.XVI and the Seedling rootstocks even at 77° F., this indicating a greater measure of tolerance to the higher temperatures than was shown by the more seriously browned M.I, M.II and M.IX.

Temperature affected root form (Fig. 2). Roots of all rootstocks at the higher temperatures were very slender and much branched, while at the lower temperatures they were much thicker and less branched.

Shoot growth.

Bud break. As with root initiation, growth responses in the dormant bud were more rapid on plants grown at a higher root temperature. The differences, however, were not significant for most of the comparisons.

Shoot elongation. Root temperature influenced shoot elongation (Fig. 3). Elongation of M.I was greatest at 55° F., M.VII at 66° F., and M.XVI and Seedling rootstocks at 77° F. The M.II and M.IX replicates at 66° and 77° F. were missing, but growth was greater at 55° than at 44° F. The most limited shoot growth for all rootstocks was in the 44° F. treatments. Leaves and stipules were larger and thicker at the optimal growth temperatures for the different rootstocks in these experiments.

Cross-sectional area. Diameters were converted to cross-sectional areas, and although the data indicate that a greater increase in cross-sectional area of the original stem occurred at temperatures optimum for growth, analysis of covariance yielded no significant differences among populations.

Comparison of cross-sectional area of new shoots gave the following results (only significant differences are included) :

M.I : max. at 55° ; 55° > 77° or 44° F.
M.IX : 55° > 44° F.
M.VII : max. at 66° ; 44° F. < all others.
M.XVI : max. at 77° ; 44° F. < all others.

With M.II and Seedlings, as has been previously stated, no statistical analyses were made on these populations ; however, it seemed that greater shoot growth of M.II occurred at 55° than at 44° F., while the Seedling rootstocks yielded greater shoot growth as the temperatures were increased from 44° to 77° F.

The corresponding comparisons for fresh and oven-dried weights of shoots, again with only significant differences included, were :

M.I : max. at 55° ; 55° > 66° or 44° F.
M.IX : 55° > 44° F.
M.VII : max. at 66° ; 44° F. < all others.
M.XVI : max. at 77° ; 44° F. < all others.

With M.II and Seedlings, although not subjected to statistical analyses, weight of

PLATE I

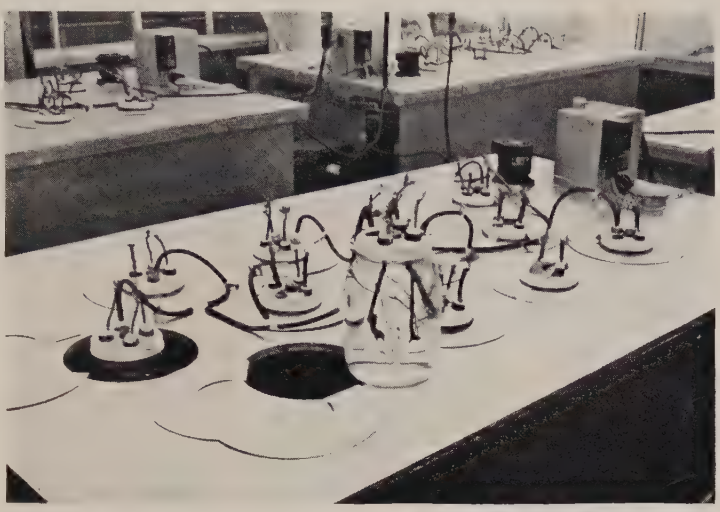

Fig. 1A.

View of controlled temperature tanks, Plant Science Greenhouse, Michigan State University.

Fig. 1B.

Close-up view of jar with aerating tube and plants inserted.

[face p. 58

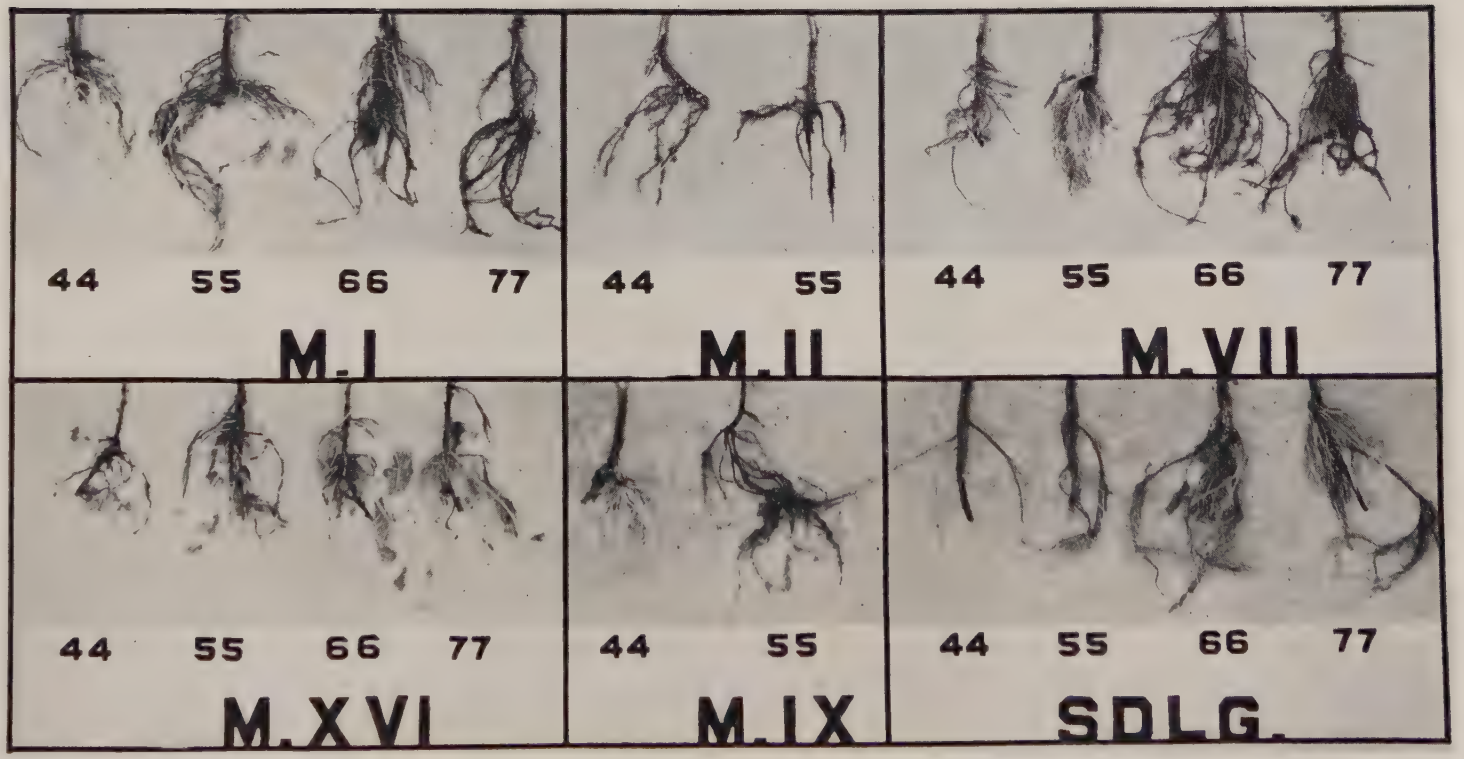

FIG. 2

Extent and growth habit of roots grown at different temperatures

PLATE III

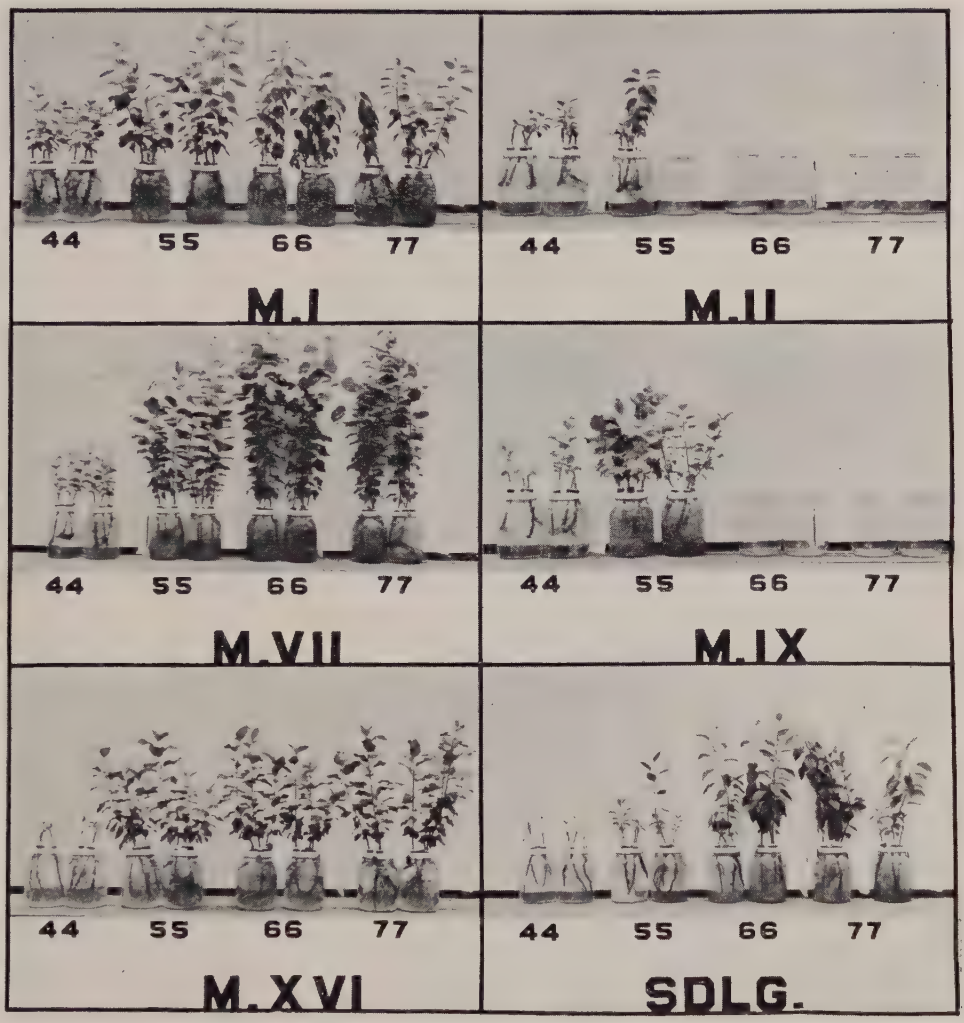

FIG. 3.

Shoot elongation and root density of apple rootstocks grown at different root temperatures.

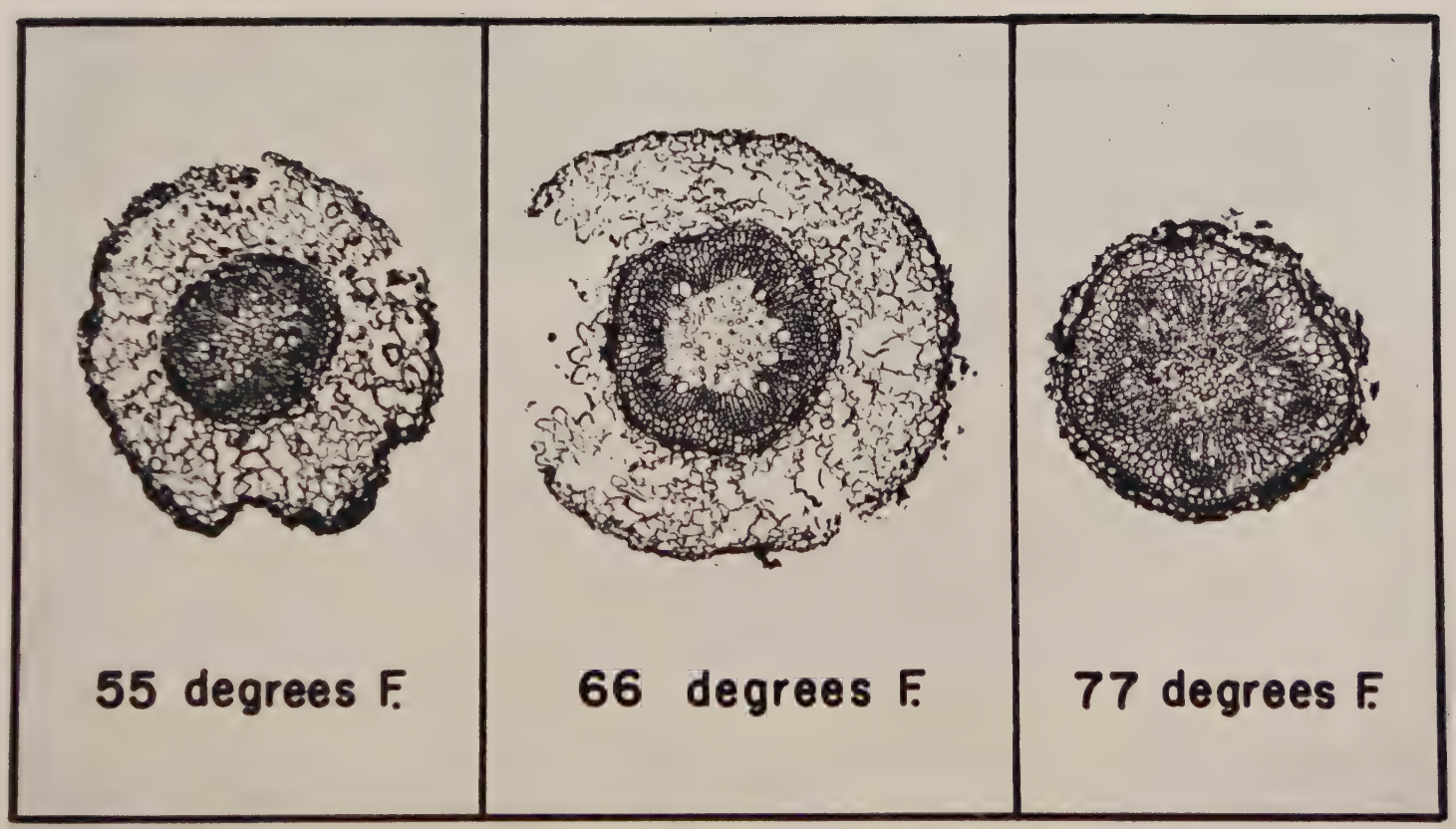

FIG. 4.

M.I roots, taken at ten centimetres from the tip, showing an increasing rupturing and sloughing of the cortical tissue with increase of temperature.

M.II shoots appeared to be greater at 55° than at 44° F. and the weight of Seedling shoots greater as the temperature was increased from 44° to 77° F.

Anatomical studies.

Root temperature affected the maturation of the root tissue. Greatest maturation occurred at 77° F. ; least at 44° F., with intermediate development at 55° and 66° F. Further, the proportion of cortical to stelar tissue was least at 77° F., greatest at 44° F., and intermediate at 55° and 66° F.

At 44° F.

At 5 cm. from the root tip, only a small proportion of the primary vascular tissue had differentiated and no cell maturation had occurred. No cambium had developed ; the pericycle for the most part was biseriate and the cortex was entire.

At 7½ cm. from the root tip, most of the primary tissues had differentiated ; cells at the protoxylem points had matured ; some cambial activity, but only on the inner edges of the phloem strands, was evident ; the pericycle had not developed beyond the incomplete biseriate phase, and the cortex was entire with no indications of sloughing.

Owing to the limited root extension at this temperature, samples at 10 cm. from the root tip were unavailable.

At 55° and 66° F.

Roots grown at 55° and 66° F. were intermediate in development between those grown at 44° and 77° F. Representative cross-sections taken 10 cm. from the tips of M.I roots for the 55°, 66° and 77° F. treatments are shown in Fig. 4.

At 77° F.

At 5 cm. from the root-tips, most of the primary tissues had differentiated, but maturation at the protoxylem points was not complete. Slight cambial activity in the phloem zone was visible ; the pericycle was two-layered and the cortex undamaged.

At 7½ cm. from the tip development was much more advanced. The primary tissues were well differentiated ; cells of the protoxylem and protophloem had matured and maturation of the metaxylem and metaphloem was in progress. Cambial activity on the inner edges of the phloem extended almost to the protoxylem points, but little radial enlargement had occurred. The pericycle was bi- and tri-seriate and had become active above the protoxylem points. The cortex was ruptured and occasionally partially sloughed off, a condition conspicuous in the M.I plants which were very prone to cortical sloughing at the higher temperatures.

At 10 cm. from the root tips the secondary tissues had developed considerably. Meristematic activity was quite evident, not only around the inner edges of the primary phloem regions, but also in the pericycle at the protoxylem points, and frequently the two areas had joined to form a ring of vascular cambium which had added secondary tissues. Cell maturation was complete in both primary xylem and phloem and even in the newly-formed secondary xylem, while the pericycle generally had reached a four-layered stage. As shown in Fig. 4, the M.I roots had lost all their cortex. In the other rootstocks the cortex was often ruptured or more or less sloughed off.

DISCUSSION.

In evaluating the results of these experiments, it should be kept in mind that the rootstocks were grown in nutrient solution. Conceivably, the reactions might be different in the nursery row under similar temperature conditions. Further, the plants were transferred abruptly from the cool temperature of the nursery cellar to the various experimental temperatures and, therefore, did not experience the gradual increase in temperature which would have occurred under outdoor conditions.

Temperature in relation to shoot and root initiation.

Apparently the rest and dormancy requirements of the East Malling rootstocks were satisfied by a storage period up to 11th February, since satisfactory new growth of roots and shoots occurred with plants so handled. Initiation of vegetative growth of both shoot and root was influenced by the root temperature for, as the temperatures increased from 44° to 77° F., new growth of roots and shoots occurred progressively earlier.

Bud break between the variously treated Seedling rootstocks was not significantly different. Inasmuch as this material was obtained from a commercial source, the dormancy of the vegetative buds may have been broken in transit and growth may have been initiated before the plants were placed in the tanks. At the several temperatures Seedling rootstocks were variable in root formation, but the frequent failure to form roots is unexplained.

Temperature in relation to root growth.

Root temperature influenced root elongation. Root growth of all rootstocks at 44° F. was poor, results similar to those found by Nightingale (1935) and Batjer *et al.* (1939).

Rogers (1939) and Proebsting (1943) found that root growth increased with progressively increasing temperatures, but in the present trial certain rootstocks showed varietal differences similar to those obtained by Nightingale and Blake (1934) with the Baldwin and Stayman apple varieties. The M.VII, M.XVI and some of the Seedling rootstocks increased in fresh and dry root weights as the temperatures were raised from 44° to 77° F., but the M.I, M.II, and M.IX rootstocks declined in performance above 55° F.

It must be remembered that the tests reported in this paper were conducted in nutrient solution and that the results may have been complicated by unknown factors which may not occur in soil. Yet, the mortality of M.II and M.IX in the 66° and 77° F. treatments, and the root growth reduction in M.I rootstocks at temperatures above 55° F. suggest that these rootstocks may prefer a low root temperature. M.VII and M.XVI rootstocks were tolerant of root temperatures from 55° to 77° F., while the Seedling rootstocks grew much better at 66° and 77° F.

As a hypothesis for further study it is suggested that some of the East Malling rootstocks may prefer a relatively cool root temperature, and that this may explain the fact that some of them have not been widely adopted on the North American continent. Thus, they have not been successful in the State of Kansas where Filinger has reported (in private correspondence, 1954) maximum soil temperatures of 101° F. and temperatures well above 90° F. for a considerable period at a depth of six inches. Tukey and Carlson (1949) reported more favourable growth of the East

Malling series in Michigan. Maximum soil temperatures (93° F.) at Michigan State University (Bouyoucos, 1916) are much below those of Kansas and are less protracted. Further, in England where these East Malling rootstocks thrive and are of great commercial importance, the highest soil temperatures encountered by Rogers (1953) were 70° to 75° F. The maximum temperatures experienced even in England would appear to be higher than optimal for the growth of some rootstocks in these experiments. These temperatures, however, are not of long duration and, as reported by Brenchley (1922), plants are better able to withstand fluctuating temperatures than a constant high temperature.

The newly-formed roots at 44° F. were pearly white, thick and unbranched, while at 77° F. they were very slender and much branched. Although the rootstocks varied in reaction to the 77° F. treatments, the cortex was considerably browned. These results are in agreement with the findings of Nightingale (1935) for apples, Shanks and Laurie (1949) for roses, Stuckey (1942) for colonial bentgrass, and Darrow (1939) for Kentucky bluegrass. Heinicke (1932) also found that apple tree rootlets submerged at high temperatures were injured severely.

Temperature in relation to shoot growth.

The data on shoot elongation, cross-sectional area of the new shoot, and fresh and dry weights of the new shoots indicated varietal differences in temperature effect. Nightingale and Blake (1934) found similar differences in the Baldwin and Stayman apple varieties.

In general, shoot growth was dependent on root growth, a finding similar to those of Nightingale (1935), Batjer *et al.* (1939), Proebsting (1943) and Rogers (1952). Shoot growth of all rootstocks at 44° F. was poor.

Temperature in relation to root anatomy.

Microscopically the transverse sections from various parts of the newly-formed roots emphasized the effects of root temperature. The findings are in agreement with those of Nightingale (1935) for apple, Shanks and Laurie (1949) for roses, Stuckey (1942) for colonial bentgrass, and Darrow (1939) for Kentucky bluegrass. An increase in temperature from 44° to 77° F. brought about progressively greater maturation in the root tissue, as illustrated by primary tissue differentiation, subsequent vascular cambial activity and deposition of secondary tissue. Increase in root temperature also caused increased browning and sloughing of the cortex. The proportions of cortical to stellar tissue were also reduced. Similar temperature effects on apple and roses were reported by Nightingale (1935) and Shanks and Laurie (1949) respectively.

SUMMARY.

To study the effect of root temperature on the growth of six apple rootstock varieties, five East Malling clones and one rootstock of Seedling origin were grown in nutrient solutions at 44°, 55°, 66°, and 77° F., but at the same air temperature.

The onset of new growth in shoot and root was accelerated by a rise in temperature from 44° to 77° F.

Definite differences in root production were evident. All rootstocks showed very slight root growth at 44° F. ; root growth in M.VII, M.XVI and Seedling

rootstocks increased as the temperature was raised from 44° to 77° F., while greatest root growth in M.I, M.II and M.IX was at 55° F. All of the last two rootstocks were killed at temperatures above 55° F.

The cortex of those plants that grew better at low temperatures was severely browned, ruptured and often sloughed at high temperatures. This condition was not so marked in varieties tolerant of high temperatures.

At 44° F., the roots were thick, pearly white and non-branched, while at 77° F. they were slender, much branched, and more or less discoloured.

Shoot growth was proportional to root growth. Shoots of M.I, M.II and M.IX were longest at 55° F. ; M.XVI was almost equally tolerant to 55°, 66° and 77° F., but growth was slightly greater as the temperature increased. The most extensive top growth was at 66° F. for M.VII and at 77° F. for the Seedlings.

Raising the root temperature from 44° to 77° F. increased root cell maturation, as illustrated by differentiation of primary tissues, vascular cambial activity and subsequent deposition of secondary tissues. The highest root temperature also increased browning and sloughing of the cortex.

Several of the East Malling rootstocks tested appear to prefer a relatively cool root temperature. It is suggested that this factor be further explored on the North American continent, where soil temperatures over large areas are relatively high for extended periods.

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(*Received* 4/6/55.)

BOOK REVIEWS

MINIATURE DAFFODILS. By Alec Gray. (London : W. H. & L. Collingridge Ltd. 1955. Pp. 57, illus. Price 15s.)

In recent years a growing interest has been taken in the miniature daffodils. This, to a very large extent, has been stimulated by Mr. Alec Gray who has carried on the work of earlier enthusiasts such as Mr. and Mrs. Backhouse, the Reverend G. H. Engleheart and Peter Barr. These delightful small plants are most suitable for the rock garden and the alpine house ; their miniature beauty is lost among the giants of the border. In his recently published book " Miniature Daffodils " Mr. Gray shares with his readers knowledge which he has gained in many years' experience in the cultivation of these plants.

Chapters on outdoor and indoor cultivation are followed by one on raising daffodils by seed. There is a simple account of hybridization, and pests and diseases likely to attack the dwarf daffodils are described briefly with their methods of control. These earlier chapters will be of greatest value to those who are not fully cognizant of general cultural details, but by far the most valuable chapters of the book to the experienced grower will be those describing the dwarf species and varieties and their requirements, and the lists of miniatures suitable for growing in sunk gardens, pans, rock gardens, window boxes, bowls of fibre, and for naturalizing in grass. The work of indexing any book on gardening must be extremely tedious, especially as there is so much confusion of plant names partly owing to the usage, by nurserymen and others, of a name which is not botanically correct. The information in this book would have been more readily available if cross referencing had been maintained throughout ; for example, *Narcissus Tazetta caniculatus* is usually listed in catalogues as *Narcissus caniculatus*. If cross referenced it would have been simpler to locate.

The book is illustrated by fourteen excellent black and white photographs and, although 15s. seems a rather high price for so slim a volume, both the beginner and the experienced amateur will find much that will interest them. M.P.

THE SOILS OF THE GLASTONBURY DISTRICT OF SOMERSET. By B. W. Avery. (London : H.M. Stationery Office. 1955. Pp. 131, illus. Price 5s.)

The soils and agriculture of an area of 216 square miles in the centre of Somerset are described in this, the second memoir of the Soil Survey of Great Britain.

Included in a short outline of soil mapping and classification is the relation of the soil series in the area to parent materials, geological formations, and to the major soil groups. A general description of the profile characteristics of each series is presented and, in the appendix, there are more detailed descriptions, together with analytical data, relating to representative profiles of each series.

The presentation of the survey data, and of the coloured 1-inch to 1-mile soil map, follows the same scheme as that adopted for the first memoir. This is a commendable policy which, it is hoped, will be maintained, as it will prove to be a most useful feature when the series of memoirs for the whole of England and Wales is complete.

In the chapter on Agriculture and Land-Use it is not surprising to read that over this area, where soils are extensively silty clay to clay in texture, the most widespread crop is grass and the predominant farming practice is dairying. This has long been established in the district and the problem of " teart pastures " was for many years a serious one. An interesting account of teart pastures is given and mention is made of the distinctive work of Dr. D. A. Osmund, who related the occurrence of the trouble to soil type, and of A. H. Lewis, who, on analysis of soil and pasture herbage, found high levels of molybdenum which proved to be the toxic element to young stock. Thus an important aspect of the Soil Survey work is illustrated.

The soils generally are unsuitable for horticultural crops, cider apple orchards and withy beds occupying only a relatively small acreage.

A further most commendable feature of these bulletins is the inclusion of a glossary providing definitions and explanations of the various pedological and chemical expressions used in the text.

J.E.G.

MUSHROOM GROWING. Ministry of Agriculture Bulletin No. 34. 6th Edition. (London : H.M. Stationery Office. 1954. Pp. 79, illus. Price 5s.)

This bulletin must already be well known to every serious mushroom grower, for this is the sixth edition to be published since 1931. And where else could he find so concisely and authoritatively stated so much of the information that he needs ?

The bulletin aims not only to describe established practices but also to acquaint the reader with the most recent developments in this country and abroad. To that end the present edition, published only four years after its predecessor, has been revised and brought up to date. It describes, with illustrations, the whole process of commercial mushroom growing and includes five appendices, one of which, on the Two-Zone or Tray System, is new.

A bibliography of over 120 references to literature, more than double the number in the fifth edition, is included. The papers are listed in alphabetical order of the authors' names ; but the method of citation, whereby the names follow the title, except for books, seems likely to irritate those who wish to refer to the bibliography frequently. Nevertheless, this publication is a mine of information, and, in these days of inflated costs, good value for its modest price of five shillings.

T.N.H.

DISEASES OF VEGETABLES. MINISTRY OF AGRICULTURE, FISHERIES AND FOOD BULLETIN No. 123. (London: H.M. Stationery Office. 1954. Pp. 80, illus. Price 4s.)

The fourth edition of the excellent bulletin on vegetable diseases by Mr. L. Ogilvie, Plant Pathologist of the South Western Province, N.A.A.S., contains several new or revised sections.

The notes on whiptail of cauliflowers have been expanded and there is a new section on watercress which deals with the very prevalent and severe Crook Root disease. Instructions are now given for the treatment of Onion Smut and White Rot by seed pelleting.

Other important additions are on the use of some of the newer fungicides, notably thiram which is recommended for the control of Onion Smut and Lettuce Downy Mildew.

The section on tomatoes has been considerably amended. Descriptions are given of Aspermy disease and of root infection by Powdery Scab of potatoes. Certain non-parasitic disorders are also described for the first time, viz. hollowness, glassy fruit and weed-killer injury. The notes on mosaic disease have been revised to draw together the various symptom types.

There are still a few minor criticisms which may be made. As in the previous editions, the crop sections are arranged in what seems to the writer to be a rather confusing order. Certain of the colour photographs leave much to be desired, particularly those of Didymella Stem Rot and Cladosporium disease of the tomato, although the other illustrations are excellent. The binding is greatly inferior to that of the third edition and the cover is most uninteresting.

The bulletin does, however, provide a most useful compendium of information, not only for the growers for whom it is primarily intended but also for all who work with vegetable crops.

W.G.K.

TOXIC CHEMICALS IN AGRICULTURE—RISKS TO WILD LIFE. Report of the Working Party on the Precautionary Measures Against Toxic Chemicals Used in Agriculture. (London : H.M. Stationery Office. 1955. Pp. 31. Price 1s. 6d.)

The Working Party, reconstituted in May, 1953, were asked " to investigate the possible risks to the natural flora and fauna of the countryside from the use in agriculture of toxic substances, including the possible harmful effects for agriculture and fisheries, and to make recommendations ". The report considers that new legislation is unnecessary, but that evidence should be examined by the Inter-departmental Advisory Committee (set up following the Working Party's second report) with a view to the framing of regulations or legislation, if desirable.

The effects of normal spraying in current practice are not regarded as serious, and casualties are few compared with other causes. Arsenicals remain the most toxic sprays to honeybees, although DNC, BHC and certain organophosphorus insecticides are very toxic. Dangers to birds and mammals, as well as to insects, vary greatly with stage of crop development ; a late aphid attack on brassicas, dealt with by organophosphorus compounds, led to many animal casualties in 1952, mainly because of lack of alternative cover at that time of year.

It is difficult to agree that " the aim of research workers, both in industry and at research stations . . . is of course that they (pesticides) should be toxic only to specific pests " (p. 3). Current industrial research and development is still in the main towards pesticides of less specificity, at any rate within a biological class such as Insects or Fungi. It remains to be seen whether true specificity can be an economic proposition.

There is useful information in the appendices, but evidence is sparse and more research is called for, especially on the interaction of spraying and animal, including arthropod, populations.

A.H.M.K.

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1. The **Journal of Horticultural Science** is an official organ of the Horticultural and Agricultural Research Station, Long Ashton, Bristol, and the Horticultural Research Station, East Malling, Kent.

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7. The **scientific names** given in the "List of Common British Plant Diseases", published by the British Mycological Society (Cambridge University Press, 1944) and "Common Names of British Insect and other Pests", published by the Association of Applied Biologists (The Mendip Press Ltd., Bath, 1947) must be employed.

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CONTENTS

The Nitrogen Content of Cox's Orange Pippin Apples in Relation to Manurial Treatments. By A. C. HULME 1

Studies on the Effects of Light Quality on the Growth and Development of Plants. I. Apparatus for the Growing of Plants under Controlled Light and Temperature Conditions. By DAPHNE VINCE, M. G. CLARKE, H. R. RUFF and R. H. STOUGHTON 8

Studies on the Effects of Light Quality on the Growth and Development of Plants. II. Formative Effects in *Lycopersicon esculentum* and *Pisum sativum*. By DAPHNE VINCE 16

Boron Nutrition of the Hop. By E. G. CRIPPS 25

Predacious Spiders in Orchards in South-eastern England. By D. A. CHANT 35

Observations on the Nature and Development of Structural Defects in the Unions between Pear and Quince. By BARBARA MOSSE and F. SCARAMUZZI 47

Effects of Controlled Root Temperatures on the Growth of East Malling Rootstocks in Water Culture. By S. H. NELSON and H. B. TUKEY 55

Book Reviews 64

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PRINTED BY HEADLEY BROTHERS LTD 109 KINGSWAY LONDON WC2 AND ASHFORD KENT